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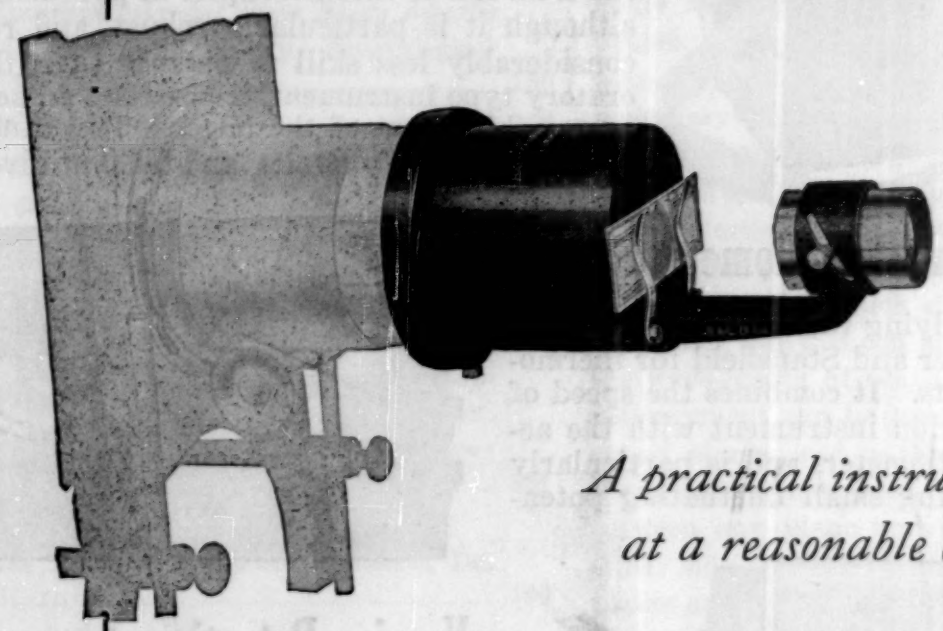

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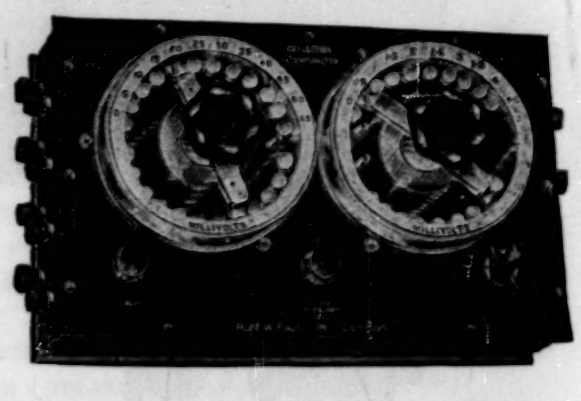

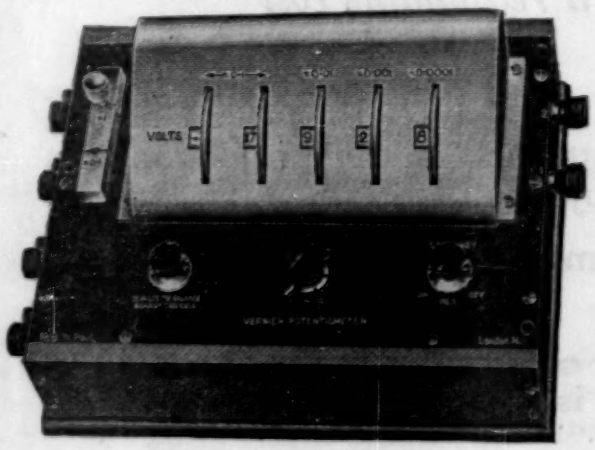

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THE ANALYSIS OF CRYSTAL STRUCTURE BY X-RAYS[1]

IN this address I propose to consider the new methods of analyzing the structure of materials by means of X-rays, considering especially the stages by which they move towards their objective. It is convenient to recognize three such stages, of which the first comprises the simplest and most direct measurements and the last the most indirect and complex.

The fundamental measurement of the method is the angle at which rays of a given wave-length are reflected by a set of planes within the crystal. The planes of a "set" are all exactly like one another: an imaginary observer within the crystal could not tell by any change in his surroundings that he had been moved from one plane to another. Sometimes there is no reflection of the first order from a set so defined, because the planes may be interleaved by other planes so spaced and of such strength as to annul the true reflection; but this can always be allowed for. When the wave-length of the X-rays is known, the angular measurement can be used to find the spacing of the set of planes, and in this way a linear dimension of the crystal is measured. The spacing is the distance between any plane and its nearest like neighbor on either side. If the spacings of three different sets of planes are found, the volume of the unit cell is found. The crystal unit cell is bounded by six faces, each set of planes furnishing a pair. The pair consists of two neighboring planes of the set. The cell may have a great variety of forms, but has always the same volume. The specific gravity of the substance being known, it is possible to find the number of atoms of various kinds which the cell contains; the proportion of the various kinds is necessarily the same as in the molecule of the substance. The cell is in practice found always to contain a small integral number of molecules, one, two, three or four, rarely more. This assemblage of molecules is fully representative of the crystal; by the mere repetition of the cell, without the addition of any new features, the crystal with all its properties is produced.

There are, therefore, three types of assemblage. The simplest is that of the single atom, as in helium in the gaseous state, in which the behavior of every atom is on the whole the same as the behavior of any other. The next is that of the molecule, the smallest portion of a liquid or gas which has all the properties

[1] Address of the president of Section A—Mathematical and Physical Science of the British Association for the Advancement of Science, Toronto, August 11, 1924.

of the whole, and lastly, the crystal unit, the smallest portion of a crystal (really the simplest form of a solid substance) which has all the properties of the crystal. There are atoms of silicon and of oxygen; there is a molecule of silicon dioxide, and a crystal unit of quartz containing three molecules of silicon dioxide. The separate atoms of silicon and oxygen are not silicon dioxide, of course; in the same way the molecule of silicon dioxide is not quartz; the crystal unit consisting of three molecules arranged in a particular way *is* quartz.

The final aim of the X-ray analysis of crystals is to determine the arrangement of the atoms and the molecules in the crystal unit, and to account for the properties of the crystal in terms of that arrangement.

The first step is the determination of the dimensions of the crystal unit cell: any one of the possible ways in which the cell can be drawn will do. When this has been completed it is a simple calculation in geometry to find the distance between any atom and any other atom in the crystal of like kind and condition, or, in other words, the distance an observer would have to travel from any point within the crystal to any other point from which the outlook would be exactly the same and would be similarly oriented. This is the only measurement which the X-rays make directly; any other measurement of distance is made indirectly, by aid of some additional physical or chemical reasoning. It is not possible by direct X-ray measurement to determine the distance between any two points—atom centers, for example—within the same cell.

Let us take an example. The crystal unit of naphthalene has the dimensions defined in the usual way by the statement:

$$a = 8.34\text{Å} \quad b = 6.05\text{Å} \quad c = 8.69\text{Å}$$
$$\beta = 122°\ 49' \quad \alpha = \gamma = 90°.$$

It contains two molecules: an integral number, as always. These facts are given directly by the X-ray measurements. But there is no direct determination of the distance between any carbon atom and any other carbon atom contained within the same cell; the measurements given are those of the distances between any atom and the nearest neighbors, in three principal directions, which are exactly like itself, these distances being the lengths of the edge of the cell. There is not even a measurement of the distance between the two molecules in the same cell, because they are not similarly oriented. In fact, there is no clear meaning in the term "distance" in this case, just as we can not state the distance between an object and its image in a mirror, unless the object is a point of no dimensions. If the molecule of naphthalene has a center of symmetry, as is indeed indicated during the development of the results of the X-ray analysis, it is possible to state the distance between the centers of symmetry of the two molecules in the same cell, but this does not define the distance between any atom in one of the two molecules and any atom in the other. All such distances, if they are to be defined and measured, can only be found by the aid of fresh considerations.

Or again, let us take the case of rock-salt. The crystal unit cell of rock-salt contains one molecule; one form of the cell has for its eight corners the six middle points of the faces of a certain cube (edge = 5.62 A.U.) and two of the opposite ends of any diagonal of the cube. The so-called face-centered cube is four times as large as the cell and contains four molecules. The dimensions of the cell are determined directly by the X-rays, which measure the distance between each of the three pairs of parallel faces that contain it. The cell may be placed so that each corner of it is associated in the same way with a molecule of sodium, let us say: and, of course, the knowledge of the dimensions of the cell is equivalent to a knowledge of the distance between any two sodium atoms in the crystal, which atoms are all alike in every respect. But we have no direct measurement by the X-ray methods of the distance between a sodium and a chlorine atom. We infer that the chlorine atom lies at the center of the sodium cell, or *vice versa*, from considerations of symmetry. Crystallographic observations of the exterior form of the cell assign to the crystal the fullest symmetry that a crystal can possess. If the cell that has been described is to contain the elements of such full symmetry, the chlorine atom must lie at the center of it. It can not lie anywhere else, for every cell would contain a chlorine atom similarly placed. There would then be unique directions in the crystal; that is to say, polarities. Moreover, both the sodium and the chlorine atoms must themselves contain every symmetry of the highest class: the full tale of planes of symmetry, axes of rotation, and so on. They both have centers, and we can state the distance between a chlorine atom and a sodium atom because we can state it as between center and center, and put it equal to half the distance between two sodium atoms on either side of the chlorine. The structure of sodium chloride is then determined completely.

It may possibly be a difficulty that the cell so described does not at first appear to have all the symmetries of the rock-salt cube, but it is to be remembered that we are to expect the full display of symmetries only when the cell has been repeated indefinitely in all directions. We may take a simple case, as in Fig. 1.

Suppose sodium and chlorine atoms were to be arranged in a line as in the figure, just as they are in

any of the three principal directions in the crystal. A plane of symmetry perpendicular to the line of atoms indefinitely prolonged may be drawn through the center of any atom. The unit cell is one molecule: one chlorine and one sodium. The unit by itself has not this symmetry, but the repetition of the same

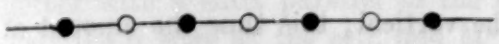

FIG. 1

molecule in either direction on either side provides the symmetry. Moreover, each sodium and each chlorine must itself have a plane of symmetry, and the planes are equally spaced. We can state the distance between a sodium and a chlorine atom as half the distance between two sodiums.

Let us take one more instance, the diamond. The crystal unit cell contains two atoms of carbon: as in the case of rock-salt, it may be so chosen that, of its eight corners, six are the middle point of the faces of a certain cube and two are the ends of any diagonal of the cube. The sides of this cell are determined by the X-rays, and are all equal to 2.52 A.U. This is the distance between any carbon atom and the nearest carbon atom which is exactly like itself. The distance between the two carbon atoms in the same cell is not measured directly, but can be inferred after it has been defined. This we are able to do because the carbon atom is tetrahedral; a tetrahedron has a center, and we can state the distance between the centers of two tetrahedra, no matter how the tetrahedra are oriented. We know that the carbon atom, as built into the crystal, is tetrahedral, because the X-ray observations show that the four trigonal axes meet in it. The two atoms in the cell are oriented differently; one may be said to be the image of the other, if translation shifts are ignored, in each of the faces of the cube. Considerations of symmetry or X-ray observations show that the center of an atom of the one orientation lies at the center of a tetrahedron formed by four atoms of the other orientation. The edge of this tetrahedron is the edge of the unit cell, and its length is 2.52 A.U. It may then be calculated that the distance between the one atom and the others, its nearest neighbors, is 1.54 A.U. We may call this distance the diameter of the carbon atom, but we must remember our original definition of the meaning of the term. Thus the 2.52 A.U. is the result of a direct unaided X-ray measurement, but the 1.54 A.U. is not, and has no meaning except after special definition.

Only such distances between atoms as can be calculated from the dimensions of the unit cell can be measured directly and without qualification. The determination of these distances may be looked on as the result of the *first stage* of the analysis by X-rays.

We now come to a *second stage.* It is possible to make other statements of the relative positions of atoms and molecules which, though less complete and informative than those of distances, and their orientations, are necessary to the solution of the crystal structure problem. These also are deduced by means of the X-ray methods.

It often occurs that the atoms or molecules in one cell can be divided into two portions which are the reflections of one another across some plane, or can be brought to be the reflection of each other by a shift parallel to the plane. In that case the orientation of the plane and the amount of the shift can be stated definitely, the former by inspection of the crystal or by X-ray observations, the latter by X-ray observations alone. So also it may happen that the atoms or molecules in the same cell may be divided into portions which can be made to coincide with each other by a rotation round some axis with or without a shift parallel to that axis. The direction of the axis can be found by inspection of the crystal or by X-ray observations; the amount of the shift can be found by X-ray observations alone.

In these cases the distances that are found by the X-ray method are all that can be stated without special definition. It is not possible to state the distance between an object and its image in a mirror, if the object has any extension in space; but it is possible to state the magnitude of a shift.

Measurements of this sort constitute a characteristic feature of the X-ray analysis, for which reason I would like to discuss them briefly.

We know that it is possible to separate crystals into thirty-two classes, according to the kind of external symmetry which they display. As we have hitherto been unable to look into the interior of the crystal, we have been obliged to be content with this imperfect classification by outer appearance. It has been shown, however, that there is a classification by inner arrangement which is perfect and includes the other. It is beyond the limits of ordinary vision: out of the range of the lens and the goniometer. The interior arrangements of the crystal, of which the outer form is one consequence, are so varied as to furnish 230 different modes. With very few exceptions the X-rays now allow us to carry the classification to this higher degree. If the modes are grouped according to the external features of the crystals that follow them, we come to the well-known thirty-two classes, there being several modes in every class. I may be permitted to illustrate this important point by examples, although it is familiar to those who have studied crystallography. Let us consider

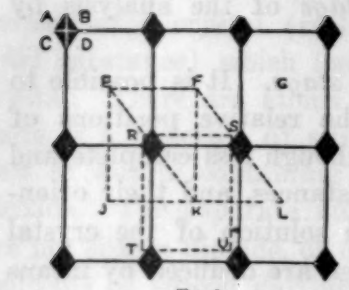

FIG. 2.

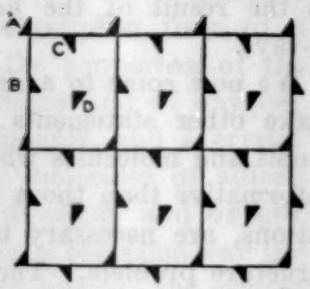

FIG. 4.

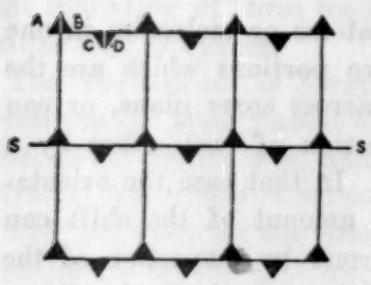

FIG. 3

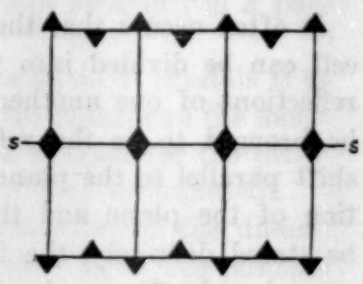

FIG. 3A.

first a two-dimensional example, which is much easier to describe than the three dimensional actuality, and contains all the essential ideas.

Consider an arrangement of figures in a plane which displays symmetry across two planes at right angles to one another. Such arrangement may be exhibited diagrammatically, as in Fig. 2. The unit cell may be drawn in various ways, EFKJ, EFLK, RSUT, and so on. The cell contains, however it is drawn, either a whole diamond or enough parts to make up a whole diamond. Each diamond can be divided into four parts: B and D are the reflections of A and C across a plane; C and D are the reflection of A and B across a plane at right angles to the first plane. Unless the diamond, the content of one cell, could be divided in this way there could not be the double symmetry. But, granted this division into four portions, it is not necessary that the four should be arranged as in the figure in order that the double symmetry may be obtained. There are two alternatives (Figs. 3 and 4).

In Fig. 3 the lower half of each diamond—that is to say, the portions C and D—are shifted, whether to right or to left is immaterial, by an amount equal to one half of one side of the cell EFKJ. The symmetry about a vertical line in the plane of the paper is obviously retained. It is not so obvious that there is still any symmetry about the horizontal line until we realize that we mean only "observable symmetry": that which is to be seen in the outer form of the indefinitely extended figure, corresponding to the crystal. Clearly, the whole figure will present the same appearance from below as from above. In fact, we can see that as a whole the lower part of the figure is symmetrical with the upper part by imagining the upper and the lower to be further shifted relatively as in Fig. 3A: the two parts sliding on one another along the line SS. The two parts are then the image of each other across SS in the full sense of the word.

From Fig. 2A we may also realize that the amount of the original shift must be equal to one half of EF: no other shift will give the symmetry which Fig. 3A shows. In Figs. 5 and 5A a different shift has been given, and the failure is clear.

In Fig. 4 not only are C and D shifted parallel to the horizontal line, but also B and D are shifted parallel to the vertical; this time the amount of shift is one half of the side EJ.

The three modes of Figs. 2, 3 and 4 all lead to the same external symmetry. There is one more which is based, as we should say, on a different lattice and is symmetrical, like the others, about two lines at right angles to each other. It is shown in Fig. 6. There are no variations of Fig. 6, as of Fig. 2, to be obtained by the introduction of shifts. If in Fig. 6 we shift C and D relatively to A and B, as we did in Fig. 3A, we find that they can now be described as the direct reflection of A′B′ into CD and of A′C into B′D, and the mode of Fig. 6A is the same as that of Fig. 6.

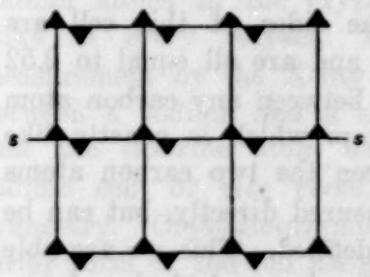

FIG. 5.

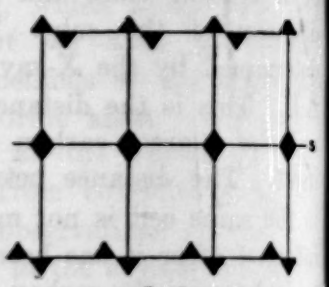

FIG. 5A.

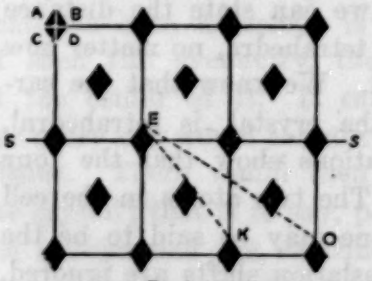

FIG. 6.

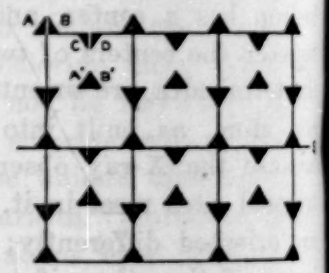

FIG. 6A.

There are therefore four *modes* in one *class:* four varieties of internal arrangement which all lead to the same external appearance of symmetry.

Our example is two-dimensional, and the crystal has three dimensions. But there are no new ideas to be added: it is only the numbers of symmetries, modes and classes that are increased. If, for example, we continue the study of the modes of arrangement that lead to an external symmetry of reflection across two planes at right angles to each other, we find that there are four lattices instead of two, and twenty-two modes instead of four. The class containing crystals that possesses this particular form of symmetry is generally called the "hemimorphic class in the orthorhombic system." Its symbol is C_{2v}: the symbols of the four lattices are Γ_0 Γ_0' Γ_0'' Γ_0'''. In every case the content of the unit cell is divisible into four parts, corresponding to the ABCD of Figs. 2 to 6.

The ten modes in the Γ_0 lattice are shown in Fig. 7, which will serve to show the numerical increase due to the introduction of the third dimension. Under each separate figure is given, beside the crystallographic symbol, another symbol which describes the shifts: D^x means a direct reflection across a plane parallel to *yz*; E^x_y a reflection across a plane parallel to *yz*, together with a shift parallel to the axis of *y* equal to half the *y* edge of the cell, and M^x a reflection across a plane parallel to *yz*, together with a shift parallel to the diagonal of the *yz* face and equal to half that diagonal.

Let us now see how the X-ray analysis distinguishes the mode. Let us imagine that Fig. 2 represented a number of pits in a plane reflecting surface. The surface could be used as a grating having many spacings instead of one. If, for example, we so placed it that the horizontal lines of the figure were parallel to the slit of the spectroscope the spacing would be equal to EJ: if the vertical, the spacing would be equal to EF. Again, if the grating were so placed that EK, for example, were vertical, the spacing would be the perpendicular distance between EK and FL. If the surface is pitted as in Fig. 3, the spacing when the horizontal line is parallel to the slit is the same as before; but when the vertical is parallel to the slit the effective spacing is only half what it was in Fig. 2. This follows from the fact that if we divided the surface into a number of vertical narrow strips the diffracting effect of each such strip, for this position, depends on the total amount of reflecting surface contained in the strip, but not on its distribution along the slip. It does not matter that C and D are upsidedown as compared to A and B. The strata consisting of C and D portions have interleaved the strata of A and B portions. This halving of a spacing of Fig. 3 as compared with Fig. 2 occurs only when the grating is placed so that the slit is parallel to the vertical line of Fig. 3, and not when any other line is vertical, except by some odd chance connected with the shape of the pits. In this way it is possible to distinguish between Fig. 2 and Fig. 3. The mode shown in Fig. 4 is distinguished by the halvings of both the horizontal and vertical spacings, and of no others. In the case of Fig. 6, as compared with Fig. 1, the spacing is halved when the slit is parallel to the horizontal or the vertical line of the figure, and also whenever the grating is so placed that the parallel to the slit passing through one of the corners of a cell does not pass through the center of that or any other cell, as, for example, if EO but not EK is parallel to the slit. It is therefore easy to distinguish each of the four modes.

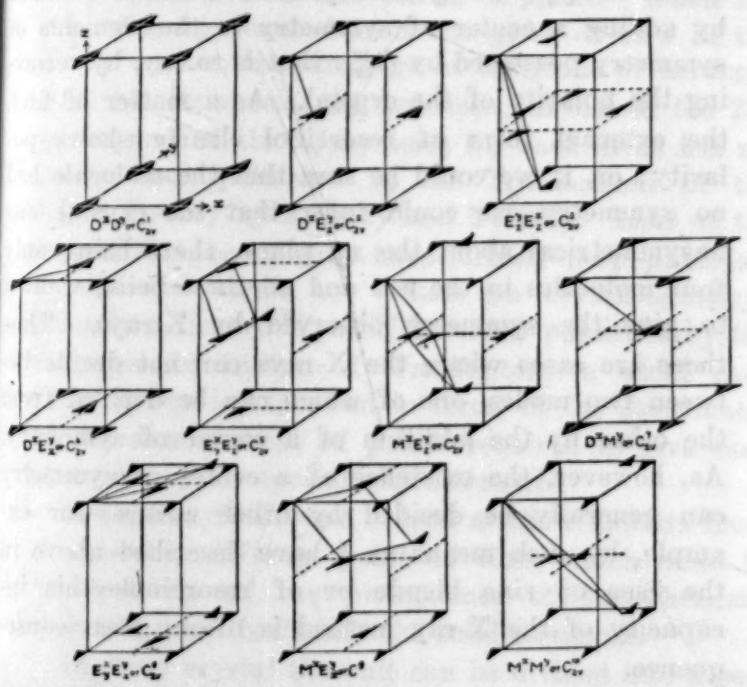

FIG 7.

Similar methods are applicable to the three-dimensional crystal. If, for example, we consider the case of C^2_{2v} or $D^xE^y_z$ we can show that, whereas in general the spacings of planes are such as are proper to a cell of the dimensions and form drawn in the figure, all planes of the form $lx/a + mz/c =$ an integer, show halved spacings, unless l is odd and m is even: which is sufficient identification of the mode of arrangement. The symbols a and c denote edges of the cell.

If we follow this line of reasoning through all the thirty-two classes, we end, of course, with the discovery of 230 modes which are known to exist: and with the identification marks of each, with certain qualifications. These last are of two kinds. One of them is general in nature and is a consequence of the fact that the X-rays can measure only the distance between two like points in neighboring cells, say A and B. But they do not indicate any difference that may exist between AB and BA. If such a difference exists it may be expected to show in the external characteristics of the cell, giving it polarity. A good example is to be found in zinc blende. Layers of zinc and of sulphur atoms alternate with one another as in Fig. 9, all of them being perpendicular to a trigonal axis of the crystal. The distance between a zinc atom in the layer A to a zinc atom in the layer B is found without question by the X-ray method. Now we know from observation of the crystal that there is a difference between AB and BA: the crystal is polar. A crystal plate cut so that its faces are perpendicular to the axis shows different properties on its two sides: if heated, one face becomes positively and one negatively electrified. Whichever face we use in the X-ray spectrometer we

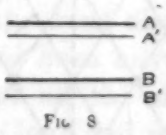

FIG 8

obtain the same value for the spacing, and we find ourselves unable to detect any difference between the two aspects by means of the spectrometer observations.

We may see this point in another way. Suppose that Fig. 9 represents a section of a crystal consisting of two kinds of atoms, indicated respectively by full and empty circles. The arrangement clearly has no symmetry about a vertical line in the plane of the paper. But if X-rays were incident from above, as shown, there would be equal reflections from the planes 11′ and 22′. If the incident rays were heterogeneous and a photographic plate were placed to receive the Laue reflections in the usual way, there would be a symmetry distribution of spots on either side of A, although there is no symmetry in the crystal to correspond.

It is only when we have taken other considerations into account and have determined the structure that we can establish the polarity of the crystal. We may take, for example, the fact that zinc blende is cubic, and therefore has four trigonal axes, a fact which we may discover from X-rays as well as from the external form. Also, the unit cell contains only one molecule of zinc sulphide, and may be drawn of the same form as in diamond: that is to say, its eight corners can consist of the six centers of cube faces and the two ends of a diagonal. If we put zinc atoms at the corners of the unit cell, the sulphur atom must lie either at the center of the unit cell or at the center

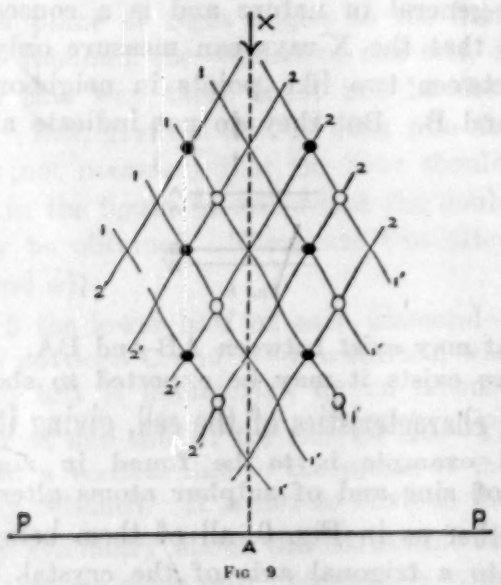

FIG. 9

of the regular tetrahedron formed by four of the corners of the cell: only by the adoption of one of these alternatives do we get the four trigonal axes. The former gives the rock-salt structure and is distinguished by the fact that the (100) and (110) spectra decrease regularly in intensity from lower to higher orders, whereas in the (111) spectrum the even orders are relatively greater than the odd. In the latter alternative the even orders of (100) are relatively greater than the odd, (110) spectra are normal and the second order of the (111) is abnormally small. It is easy to distinguish between the two cases. The latter is adopted by zinc blende. Each atom has the symmetry of Class 31, to which the crystal belongs, there being only one atom of each in the unit cell.

In this case we are successful from X-ray measurements alone in determining the mode of arrangement of the crystal, although the crystal is polar and the X-rays can not detect polarity directly. We have been able to determine the structure completely, and the polarity then appears.

When the determination of structure can not be carried far enough, the X-rays may fail to decide between the presence and absence of polarity. For example, resorcinol is an orthorhombic hemihedral crystal: this is known by its external form. The X-rays show that, this being so, its internal arrangement must be that of $M^x M^y$ or C_{2v}^{10} in Fig. 7. If we had no help from the study of external form, or from any other source, we should not be able to decide between C_{2v}^{10} and the more symmetrical mode known as Q_h^{12}: the symmetry of the latter is obtained by adding a center of symmetry to the elements of symmetry possessed by C_{2v}^{10}: that is to say, by removing the polarity of the crystal. As a matter of fact, the external form of resorcinol clearly shows polarity: or, if we could be sure that the molecule had no symmetry, we could infer that the crystal was unsymmetrical about the *xy* plane, there being only four molecules in the cell and all these being wanted to give the symmetry observed by X-rays. Thus there are cases where the X-rays can not decide between two modes, one of which can be derived from the other by the addition of a center of symmetry. As, however, the existence of a center of symmetry can generally be decided by other means—for example, by such means as I have described above in the case of zinc blende or of resorcinol—this incapacity of the X-ray method is of no great consequence.

The addition of a center of symmetry moves a structure from one class to another—Class 1 to Class 2, Class 31 to Class 32. Consequently, the X-ray methods are by themselves sometimes in doubt between two modes in different classes when they are rarely in doubt as to the mode within a class. It will readily be understood that the doubt as to class may be of far less importance than the doubt as to mode; though hitherto the former kind of difference has been given all the attention because it has been the only kind that could be observed. A very slight relative movement of the atoms would be sufficient to reduce the symmetry of the crystal from one class to another: but the change from one mode to another

within the same class would mean a complete rearrangement of the molecules.

There are two cases in which the X-rays can not distinguish between two modes in the same class. These are Q^8 and Q^9 in the enantiomorphous class of the orthorhombic system, and T^3 and T^5 in the tetartohedral class of the cubic system. The ambiguity disappears, however, if there are only two molecules in the unit cell, when the former alternative is alone permissible in each case: it would disappear also in any case in which the structure could be determined completely by any other means.

It has been known for many years, thanks to the work of Fedorow, Schonflies and Barlow, that the 230 modes of arrangement represent all the possible forms of internal crystal structure. In each mode of arrangement there is a relative disposition of planes, axes and center of symmetry, which is characteristic of the mode, and the mode may be described in terms of these symmetries. This was the language used in the original work on the subject, and the term space group was used, instead of the term mode of arrangement, in reference to the particular group of symmetry planes, axes and center in space. When the subject is approached from the point of view of the X-ray worker, the language of the mode of arrangement has its special conveniences. A list of the 230 modes and of the X-ray tests for each mode has recently been published in the Transactions of the Royal Society by Astbury and Yardley. Lists of the same 230 space groups have already been published in different terms by writers on crystallography: recently a list by Wyckoff has been published by the Carnegie Institution of Washington, in which each space group is expressed in terms of the coordinates of the arrangement of points required to give each space group its special characteristics.

It may be of interest to look at these matters from a somewhat different point of view, which takes in the question of the permanence of the chemist's molecule when built into the solid structure.

In every crystal the unit can be divided into a certain number of parts, each of which has no symmetry of its own, but may be made to coincide with any other part by some combination of reflections, rotations and shifts. The number is always either one, two, three, four, six, eight, twelve, twenty-four or forty-eight. The division into 230 modes of arrangement refers to the arrangements of these parts. In the case of a crystal of the rock-salt type both the positive and negative portions of the cell can be so divided. Very often the part in question is the chemical molecule. For example, the cell of the monoclinic prismatic class can be divided into four such parts. The X-ray measurements show that the unit cell of benzoic acid which belongs to this class contains four molecules. Also they detect the existence of the four parts, and determine the mode of their arrangement. It is natural to make the assumption that each part is a molecule. This, it may be noted, involves the existence of right- and left-handed molecules, as built into the crystal.

Sometimes the division into parts involves the division of the molecule. The molecule then consists of two or three or more parts, and therefore possesses a corresponding symmetry. For example, the naphthalene molecule in the naphthalene crystal contains two parts, and has a center of symmetry. The molecule of FeS_2 in the crystal of iron pyrites consists of six parts, and has a center of symmetry and a trigonal axis. Each of the two atoms in the rock-salt cell, sodium and chlorine, has—that is to say, its relations to its neighbors have—forty-eight parts, and therefore the full symmetry of the crystal.

Much more rarely a part consists of more than one chemical molecule. So far a few instances have been met with. The "part" in the crystal cell of sulphur certainly contains two, perhaps more, atoms. Miss Yardley finds that the "part" in the fumaric acid crystal contains three, perhaps six, of the molecules as ordinarily defined $(COOH.CH:)_2$. In the cell of α-naphthylamin at least three molecules go to a part. The part has no symmetry, so that the molecules that compose it differ from each other in some way. These are really examples of polymerization in the crystal.

Is the grouping of the atoms in the molecule as displayed in chemical reactions maintained without change? When the first results of the new methods were published, with their determinations of diamond and rock-salt structure, there was some unnecessary alarm as to the apparent disappearance of the molecule. If there had been anything to suggest a complete disruption of all the alliances in the molecule, which had been so long and so successfully studied by the chemists, the alarm would have been justified. Atomic bonds would have been annoyingly variable and dependent on conditions, and we should have been put back to the starting point in the investigation of the solid. This condition of things appears, fortunately, to have no existence. The conclusions of chemistry are carried into the solid, with only such modifications as might reasonably be expected. Our new science is in full and close alliance with chemical science already established: it is in fact a constant and delightful experience to find some direct confirmation or illustration of an inference already drawn from other sources. So far as experience has to tell us, the chemical molecule generally takes its place as such in the crystal structure with little change.

To sum up, we are now able to replace the rough

division into thirty-two by the finer division into 230. This is advancing a whole stage towards the final solution of the structure problem. We carry the analysis right up to the limits which can be foreseen by the mathematical investigation of the geometry of space. We require only a sufficient number of X-ray measurements: if these can be obtained, the crystal then—with certain additional information as to polarity—can be assigned to its particular mode or space group, with one or two exceptions as already noted. It may be that the structure of the crystal is so simple that having got so far the full solution is already in sight. In the vast majority of cases this is not so; we have only come to the end of the second stage of the work.

The first stage was complete when we had found the dimensions of the crystal unit cell: the second is completed when we know which of the 230 possible arrangements of molecules, or, in other words, space groups, the crystal structure follows.

If the structure of the crystal is not yet obvious—and in the great majority of cases this is far from being the case—we enter on a third stage, in which the mode of procedure is less stereotyped and more difficult, perhaps all the more interesting. We have now to find, if we can, the arrangement of the atoms within the cell, to which task the knowledge already gained is an indispensable though, it may be, a quite insufficient contribution.

As I have said already, the X-rays do not tell us directly the relative positions of the atoms within the unit cell. They have, however, much to tell us as to the relative intensities of the different orders of reflection by each plane, and these must depend on the atomic arrangements. It is to be admitted, however, that we are as yet unskilled in the interpretation of this evidence. We do not completely understand how varying conditions affect intensities of reflection, though we have learned a great deal through the work of W. L. Bragg, Darwin, Compton and others. And, of course, when the cell contains many molecules, their positions being as yet unknown and their separate contributions to the intensities in any case doubtful, the observations of intensity are very difficult to make use of, though they can be accurately measured. We can only avail ourselves of such bold indications as that a very strong reflection implies the location of many atom centers on or near the plane in question, particularly if there are higher orders: or we may find ourselves able to show that an especially strong second or third or other order implies the adoption of some particular alternative arrangement. A very interesting example of a general influence of form upon intensity is to be found in the reflections from the fatty acid layers which have been investigated by Muller and Shearer. The first, third and other odd orders are much more intense than the second, fourth and other even orders. A simple explanation is found in the fact that these long chains face opposite ways alternately, and that the number of scattering centers is distributed fairly evenly along their length. At the ends, however, the uniformity of distribution is interrupted; at one end, probably the carboxyl end, there is an excess per unit length; at the other, the methyl end, a deficiency. Thus we may say that the effect on an odd order of the spectrum due to a single layer, the thickness of a layer being twice the length of a molecule, contains a factor:

$$A \sin(\omega t - \alpha) - B \sin(\omega t - \alpha - \overline{2n + 1}\pi) = (A + B) \sin(\omega t - \alpha).$$

The factor for an even order is:

$$(A - B) \sin(\omega t - \alpha).$$

If at both ends there had been an excess of scattering centers, we should have found the even orders stronger than the odd: the effect we find, for example, in the (111) planes of rock-salt. In the case of the simpler inorganic crystals like rock-salt, diamond and so on, intensity observations are conclusive as to the structure: in the case of iron pyrites or calcite they are very nearly so. But in the case of quartz, where the cell contains nine atoms, still more in the case of an organic compound, they do not carry us very far. We hope that greater experience will give us in the future the power of using them to better advantage.

In what other direction then shall we look for additional means of approaching more nearly to the final solution of the problem of structure?

The answer to this question will take account of all the store of physical and chemical knowledge which we already possess. Having solved, wholly or in great part, the structure of some of the simpler crystals, and being able to proceed in all cases, even of the most complicated crystals, to the determination of the number of molecules in the cell, and of their mode of arrangement, we must try to correlate what we have found with the properties of the crystal. By that means we shall become gradually more certain of the general connection between the structure and its physical and chemical properties; we shall become able to settle further structural details in various cases, and so, by alternate and mutually supporting advances, we may hope to reach our goal.

Let us consider what is being done in this direction. First of all there is the question of the distribution of the atoms in space. Given so many atoms, to be packed into a cell of known dimensions, what information have we as to the space that each must occupy? The answer to the question can not be simple, because we may not expect that the atoms are always to be treated as spheres, still less as

spheres of constant radius. It is as generally difficult to state the distance between one atom and another as to state the distance between a table and a chair. Nevertheless, the atom-radius is a useful conception, especially when its dependence on the nature of combination is taken into account. The question has been considered by W. L. Bragg, Wyckoff, Davey and others, and it appears that an atom does make a definite contribution to the distance between its center—when it can be assumed to have a center—and the center of a neighbor, so long as the nature of the bond remains the same. This is a valuable contribution to the study of structure. It is proved by the examination of simple structures like those of the alkaline halides, and we may assume its reliability in our attempt on more complicated problems. And, of course, it is interesting from the point of view of atomic structure itself and atomic linkages.

The radius seems to depend on the tightness of the bond as in bismuth or in graphite, where there are two kinds of bonding, and the plane of cleavage cuts across all the longer distances from center to center. In calcium fluoride the centers of calcium atoms are closer together than they are in the metal itself in spite of the interposition of the fluorine atoms; and in calcium oxide they are still closer. The change in the type of the bonding has altered the value of the radius.

There is also the very interesting but still more unsettled question of the mutual orientation of the bonds between an atom and its neighbors. It is, of course, the carbon atom which is the occasion of this problem in its most pressing form. In the diamond the exactly tetrahedral arrangements of bonds is associated with great rigidity, which implies great stiffness of orientation. The analysis of the structure of graphite has lately been carried by Bernal to a stage very near completion, but the only point in any doubt is unfortunately the very one as to which certainty would be welcome. Has the great weakening of one bond interfered with the relative orientation of the other three? Debye thought that the structure was trigonal, and that the atoms were arranged in layers which were like the layers of diamond, except that they were flattened out without a sideways extension of the network. This would involve a closer approach of carbon atom centers from 1·54 A. U. to 1·45 A. U.; against which no obvious objection can be offered, but it would be interesting to know how it happened. Hull believed the structure to be hexagonal, and that the layers remained as in the diamond. Bernal, having found some good graphite crystals to which the single crystal methods could be applied, finds that Hull is correct as to the hexagonal structure, but inclines to the belief that the layer is flattened. In the latter case, we must suppose that the carbon atom has three very strong bonds almost coplanar with the carbon and one weak bond at right angles to this plane.

The question arises in another form in the investigations of the long carbon chains by Piper and others, and especially by Muller and Shearer. If the chains are formed by the linking of carbon atoms together in such a way that the junctions of one atom to its two carbon neighbors are inclined to one another at the tetrahedral angle of 109°28′, as in diamond, then there are three possible forms of chain. In one of them, each two carbon atoms imply an increase of 2.00 A. U. in the length of the chain, and, in a second, an increase of 2.44 A. U. In these two cases the carbon atoms of a chain can lie in a plane. With one exception, all the cases examined show one or other of these two rates of increase. The third form of chain is a spiral, for which the growth of each single atom added is 1.12. In one case this rate of increase is found to hold: it is that in which the chain contains a benzene ring. This agreement between calculation and experiment shows with some force that the relative orientation of the bonds is maintained. Even when two or four hydrogens are stripped from the chain at various points, so as to leave a double or triple bond between consecutive carbon atoms, to adopt the ordinary chemical language and theory, no measurable change is found in the length of the chain. This does not mean that there is no change in the distance between neighbors: such a change would be small and might escape detection. But it does mean that there is no great change in the general straightness of the chain, such as might be expected from any large change in the mutual orientation of the bonds between the carbon atom and its neighbors.

In calcite the three oxygens which surround a carbon atom must lie in one plane. It is supposed, however, that in this case the bonds are electrostatic: the carbon atom has lost its four valency electrons, and with them its powers of tetrahedral orientation.

Now if we can discover the extent to which an orientation is maintained under different conditions we are provided with one more guiding principle in our attempt to discover the structure of the crystal which contains carbon atoms. And, of course, the organic compounds center round the carbon atom and its tetrahedral structure.

The question of orientation in respect to other atoms is more obscure, but it is clearly one of importance. There must be some reason why ice has such an open structure, and here the oxygen atom is largely concerned. In the ruby the oxygen atom has no plane of symmetry in relation to its neighbors. In organic substances the great emptiness of the structure implies that atoms are attached to one

another at points which have definite positions on the surfaces of the atoms and are limited in number. And, generally speaking, the consideration of organic crystal structure is against any idea that atoms and molecules are to be treated as spheres surrounded by uniform fields of electric force, except in certain cases where by loss or gain of electrons an atom has been reduced to the outer form of one of the rare gases. They must have highly irregular fields, having forms which more or less resist any change. The weak bonds which hold molecule to molecule in the organic substance are not due to electron sharing as in diamond, or to ionization as in rock-salt, but to an intermingling of stray fields belonging to definite positions on the surfaces of the molecules.

Our attempt to discover the effect of orientation is part of a general attempt to discover the field of force of the atom, which is naturally a very difficult matter. But if we can learn only a few rules, even empirical rules, we are so much the further on our way.

Yet another obvious and most important source from which help may be obtained is to be found in chemistry itself. Although the chemist has had no means until now of measuring distances and angles, he has been able to build up a wonderful edifice of position chemistry. An atom A of a molecule is certainly linked, it may be to B, and not to C; or again, of a number of atoms of the same nature and contained in the same molecule, so many must be alike, and so many may be different.

The chemist has, for example, come to the conclusion that the naphthalene molecule is a double benzene ring, and the anthracene a triple benzene ring. The X-ray observations show that one of the sides of the unit cell of the latter crystal is longer by 2·5 A. U. than the corresponding side of the other, all other dimensions of the two cells being very nearly the same. The width of the hexagonal ring in the diamond is 2·5 A. U., so that on the one hand the chemical evidence suggests that the length of the molecule is parallel to that edge of the two cells which shows differing values, and on the other the X-ray conclusions give material support to the chemical view. Let us take another example from basic beryllium acetate $Be_4O(C_2H_3O_2)_6$. The substance is remarkable for the ease with which it sublimes into a vapor consisting of whole molecules, from which we may infer that the molecule does not suffer much change in the process. The relative positions and mutual alliances of the atoms are nearly the same when the molecule is free as when it is built into the solid. From the X-ray evidence we learn that the molecule has four intersecting trigonal axes. We must place the unique oxygen at the center of a regular tetrahedron, and the four beryllium atoms at its corners. Each of the six acetate groups must be associated with one of the tetrahedron edges, and in such a way that the four trigonal axes are maintained. This necessitates, as crystallographic theory shows, the existence of a dyad axis through the middle points of each pair of opposite edges of the tetrahedron. The $C_2H_3O_2$ groups must be added so as not to interfere with the existence of these axes. If they are placed correctly for the trigonal axes, each of them has a dyad axis of the kind mentioned. All this agrees with the chemical evidence as partly stated in the formula, which implies:

(1) That there is one oxygen differently situated to the rest.

(2) That the four beryllium atoms are all alike.

(3) That the acetate groups are all alike.

Further, chemists would say that the carbon atoms are not alike; in that case, they must both lie on the dyad axis, since if they did not they would necessarily be symmetrically placed with respect to that axis and would be equivalent. On the other hand, the oxygen atoms in the acetate group can not lie on the axis if, as is probable, they are equivalent to one another. They must be placed symmetrically with respect to the dyad axis. As to the hydrogens, we must assume either that they do not count, which is not at all unlikely, or that they are not all alike. It is impossible to place eighteen hydrogen atoms so that the group has four intersecting trigonal axes and that every hydrogen is like every other. The molecule has no plane of symmetry, the fault lying with the oxygens. It could not be due to the hydrogens because there are marked differences in the intensities of reflection of pairs of planes, which differences would not exist if there were planes of symmetry, and would be small if due to dissymmetry in the positions of hydrogens only. It is by reasoning along such lines as these that X-ray evidence and chemical evidence can help each other. Many other instances might be given; indeed, no complex crystal can be studied with success without calling in the assistance of chemical arguments.

A fourth example of the connection between arrangement and properties is to be found in the recent work by W. L. Bragg on the indices of refraction of crystals. It has been found possible to calculate the indices of refraction of calcite, given the dielectric capacities of calcium, carbon and oxygen atoms separately. The difference between the two principal refraction indices is almost entirely due to a difference between the dielectric capacities of a set of three oxygen atoms, at equal distances from one another, when placed:

(1) So that the plane in which they lie contains the direction of the field.

(2) So that this plane is perpendicular to the field.

If we are able to calculate the refractive indices on these data, then it must be possible to find conditions governing the arrangement of the atoms, when we know the composition of the crystal and its refractive indices. For instance, the near equality of the refractive indices of potassium sulphate implies that the dielectric capacity of the SO_4 group is much the same in all directions, and this is in agreement with the hypothesis that the oxygen atoms are grouped in some sort of tetrahedral fashion about the sulphur atom.

There are still other connections between structure and properties which we begin to understand, and can use in proportion to our understanding. The cleavage plane, and the occurrence of certain faces in preference to others are connected with the nature of the bonds and the size of the spacings. We are not surprised to find that in bismuth or graphite or naphthalene the cleavage plane cuts across the ties which we should expect to be the weakest of those that bind the molecules together; or again, that natural faces follow the planes that are richest in atoms or molecules and may be assumed to contain relatively large numbers of linkages. In naphthalene the cleavage plane passes between the ends of the molecules, where the β hydrogens are, and where there is a deficiency in the number of scattering centers, as the X-rays indicate by the strengths of several orders of the (001) reflection. The other faces found on the crystal cut across the ties at the positions of the α hydrogens.

There are many other connections between the structure and other properties of a substance, such as dielectric capacity, rigidity and compressibility, conductivity both thermal and electric, magnetic constants. In fact, the only properties of solid bodies which are not directly and obviously related to crystal structure are those, few in number, that depend on atomic characteristics alone, such as weight; and the absorption coefficients for α, β, γ and X rays, all the rays which involve high quantum energies. With few exceptions every aspect of the behavior of a solid substance depends on the mode of arrangement of its atoms and molecules. We have, therefore, an immense field of research before us, into which the X-ray methods have provided an unexpected and welcome entrance.

They tell us directly, as I have said, the number of molecules in the crystal unit cell, and the mode of their arrangement with such determination of lengths and angles as are required to define the mode of arrangement in full. They leave us then to ally our new knowledge to all that we possess already as to the physical and chemical properties of substances. By this comparison we hope in the end to determine the position of every atom, and explain its influence through its nature and position upon the properties of the substance. It is the chemistry of the solid that comes into view, richer in its variety even than the chemistry we have studied for the past century, and possessing an importance which is obvious to us all. Every side of scientific activity takes part in this advance, for all sciences are concerned with the behavior of matter.

W. H. BRAGG

REMINISCENCES OF LORD KELVIN

ON the hundredth anniversary of the birth of Lord Kelvin, celebrated by the scientific world, it may be permitted for the writer to record personal experiences of his kindness and impressions of his interesting personality.

When in England among the scientists in the late eighties of the last century, it was most gratifying to receive from Lord Rayleigh a letter of introduction to Sir William Thomson. When Lord Rayleigh came to America to attend a meeting of the British Association in Canada, he visited the laboratories of Wellesley College and was graciously disposed to put in the way of the first woman undertaking a department of physics in a college access to the best in her subject in England.

Though it was summer and vacation in the University of Glasgow, there was received from Lady Thomson a cordial letter, stating that she and Sir William were to come up from their country place in Ayrshire to assist in doing the honors in the university for the British Medical Association, then in session. She enclosed a card of invitation to the reception to be given to the medical men and asked me to come at nine o'clock to go with them.

At the appointed hour I was welcomed by our host, a man of quiet, almost quaint appearance and manner, but shining from his kind eyes a winning friendliness. Lady Thomson, in garnet velvet, tall and handsome, quite resplendent with pearls and diamonds, stood beside him. The reception was in the stately Gothic senate chamber, lately given to the university by the Marquis of Bute. All the faculty in academic dress and the ladies were gathered on the daïs.

After being presented to Principal Caird and others, from a point of vantage amid the brilliant group, one saw all Glasgow, much of Edinburgh and the British doctors file past.

It was evident that Lady Thomson was the acknowledged social leader, and that Sir William was the one whom all the guests were most eager to meet.

The next day several memorable hours were spent

in the laboratories, where much was going on. Half a dozen alert young students, some of whom have since become distinguished, were at work; here they were hands and feet under the control of the master mind, trying one device and then another to overcome difficulties in the performance of instruments later perfected. I sat by and watched how the mind of the original investigator works. His luminous face was an interesting study. Later he explained the evolution of his quadrant electrometer and siphon recorder, showed early models of cable devices and told dramatic experiences on his three Atlantic cable-laying voyages.

He told of Maxwell's great works—said he had not mastered all his equations yet—"I took a pull at them after returning from the reception the night before" he added. Lady Thomson showed the note-books he always kept about to catch new ideas or develop old ones; sometimes these were called to service in the night, which reminds one of Emerson, who used to wake up his wife because he had a thought. Sir William took me to his lecture room; showed his shoemaker's-wax experiment, in which the lead bullets from above and the wooden cubes from below were working their way through, as he conceived the earth ploughs through the ether. He showed his "secular experiment," as he called it, which he said was to go on for a hundred years to show the rate of travel of molecules. One wonders if that long tube is still on the wall of the Glasgow laboratory.

Going to the house for tea, the African parrot was introduced—"Dr. Red-tail, alias Parnell or Donnelly, because he is an obstructionist, and if he can not have his way makes it impossible for others to have theirs."

Sir William talked of Scotch history, of Prince Charlie and Jacobite music, of Highland legends, of American politics.

In contrast to many other English and German scientists, Sir William seemed neither surprised nor alarmed that a woman should devote herself to mathematics and physics. This was thirty-five years ago.

Some months later the meeting of the British Association of Science was at Bath. It was an epochal meeting, for the work of Hertz, showing the identity of light and electricity, thus verifying the prediction of Maxwell, was just being discussed and "Section A" was full of excitement. The American stranger was taken under the kind care of Lady Thomson, who was always at her husband's elbow, correcting his proof or amending his absent-mindedness, saying, "Sir William, here is so and so, you must meet him."

Through their kindness a dinner at the beautiful home of their host, a nephew of John Bright, was enjoyed. It was worth while to listen to the brilliant conversation between Sir William and Jannsen, the distinguished French astronomer, Oliver Lodge, Glazebrook and other like guests.

After ten years it was again my good fortune to be at another notable meeting of the British Association at Liverpool. The x-rays had just been discovered, and Lenard, who did the pioneer work, was a guest of honor. It was here a sidelight on the personality of Lord Kelvin, for he had now been elevated to the peerage, to see how all the Englishmen of science not only revered but loved him.

To hear the veterans, Kelvin and Stokes, in high debate with other giants of science as to the "particular go" of the half-dozen new kinds of radiation lately discovered was something to remember.

Lord Kelvin asked me to a private séance with Lenard and his tubes. His child-like ingenuousness was delightful. While every one was hanging on his words, his attitude was always that of the questioner and learner.

This was deeply impressed in the final experience I had with Lord Kelvin. He was to lecture in Faraday's Theater in the Royal Institution in London. Professor Dewar sent tickets and an invitation to a reception given at his house after the lecture. It had became a rare thing for Lord Kelvin to lecture, and a notable audience was gathered from all the universities to honor the occasion. Every one was in full dress, as is the wont at these famous Friday evening lectures. The semi-circle of men fronting the lecturer was remarkable, every man of international reputation—Lord Rayleigh, who discovered argon, Ramsay, of helium fame, Crookes, of the cathode rays, Huggins, "father of the new astronomy," and a score of others almost as noted. Lord Kelvin spoke slowly, with singular unconsciousness of his audience. He seemed to be rather thinking aloud and watching his experiment with intent look and uplifted finger, looking for the result as if to learn something new himself.

Lord Kelvin was great enough to lead the mathematical physicists of his day and kind enough to give the inspiration of his talk, and answer patiently the questions of eager young students.

Sarah Frances Whiting

SCIENTIFIC EVENTS

THOMAS CORWIN MENDENHALL

A memorial to Dr. Thomas Corwin Mendenhall, prepared by the committee on necrology, was presented at the meeting of the Ohio Academy of Science at Columbus on April 19, by Professor Herbert Osborn. The memorial reviews Dr. Mendenhall's life and services to science, which were the subject of a special article by Mr. G. R. Putnam

printed in the issue of SCIENCE for July 11, 1924. The concluding part of the memorial of the Ohio Academy is as follows:

Dr. Mendenhall's active connection with our Ohio Academy of Science began shortly after his return to Ohio in 1912 and he has been a devoted and helpful member interested in promoting its every interest. Almost as soon as he had acquired membership he was elected president, a quite unusual proceeding. This occurred at Oberlin meeting, 1913, and he served for the year 1914 with such skill and enthusiasm as to give us all renewed courage and confidence in the mission of the academy.

As trustee and for a number of years chairman of the research fund of the academy, serving from 1916 to his death, he was greatly interested in the use of the academy funds for research and used rare discrimination in the assignment of its limited income to secure the largest benefits in the encouragement of research.

He was particularly interested in the securing of larger support for the academy, and served most faithfully on the legislative committee which sought state support for the academy activities, especially for publication of the results of scientific studies. He expressed the hope, and it was one of his cherished projects, that the academy might be provided with a suitable building for its permanent home and as a center of its activities and that it might serve in some very vital way for the promotion of the scientific functions of the state. His recommendations and suggestions are matters of recent record and may serve us in our future efforts for the development of scientific activities in the state.

With all these relations the thing we feel most deeply to-day is the friendly nature of his work among us. With the most unusual experience in scientific development of more than half a century, a remarkable acquaintance with scientific work and workers he possessed such a broad appreciation of the work and accomplishments of others and such a friendly attitude toward even the most humble worker in the field of science that his presence and interest were a constant source of encouragement. With a multitude of honors and distinctions he was still one of the most democratic and unassuming of men. With a wealth of achievement, seldom equalled, to his credit he was ever modest in reference to the importance of his own contributions to science. He was a man whom we could admire and love, whose friendly greetings will be missed but whose memory will be cherished as representing the finest spirit of scientific devotion, achievement and fellowship. We have recorded our esteem and appreciation of his worth in such honors as it was in our power to give. We have now to place on record, as our lasting recognition, this declaration of our high regard for his service, our great indebtedness for his many activities in the academy and our tribute to his memory as a friend and fellow worker. His fine accomplishments and inspiring personality will long remain with us as a beautiful memory.

HERBERT OSBORN, *Chairman*,
A. D. COLE,
WM. MCPHERSON

MINNESOTA EXPEDITION TO THE HAWAIIAN ISLANDS

THERE has been organized at the University of Minnesota an expedition to the Hawaiian Islands to make a survey of the marine fauna and flora along the coast, with special reference to the algae and the food of fish. Members of the expedition include: Dr. Josephine Tilden, professor of botany; Dr. W. A. Riley, chief divisions of entomology and economic zoology; Dr. Henry A. Erikson, chairman, department of physics; Dr. R. A. Gortner, professor of plant physiology; Dr. J. Arthur Harris, professor of botany; Dr. Shirley P. Miller, instructor of anatomy, and Dr. Royal N. Chapman and Dr. William E. Hoffman, of the department of zoology.

The occasion of the trip is the First Pan-Pacific Food Conservation Conference. Members of the Minnesota group are among the delegates representing the United States. Following the termination of the conference the group will remain for the rest of the summer in the Hawaiian Islands where they will begin their research investigations which are closely related to the purposes of the conferences. This work will be a cooperative study of the plants and animals inhabiting the waters bordering on the islands with especial emphasis upon their relations to the production of human food.

THE PRIZE ESSAY AWARDS OF THE AMERICAN CHEMICAL SOCIETY

ACCORDING to *Industrial and Engineering Chemistry*, Secretary of Commerce Herbert Hoover, chairman of the National Awards of the American Chemical Society, has announced that six four-year scholarships to Yale University, consisting of tuition fees and $500 a year in cash, have been awarded to the following students:

DONALD VIVIAN, Phoenix, Ariz., "The relation of chemistry to health and disease."

JAMES C. REID, Dallas, Texas, "The relation of chemistry to the enrichment of life."

OLIVER C. PITTMAN, Commerce, Ga., "The relation of chemistry to agriculture and forestry."

ELTON R. ALLISON, Centralia, Wash., "The relation of chemistry to national defense."

BENJAMIN NASSAU, Hartford, Conn., "The relation of chemistry to the home."

EUGENE R. BROWNSCOMBE, Santa Rosa, Calif., "The relation of chemistry to the industries and resources of California."

Over 500,000 students all over the United States competed, and six prizes of $20 in gold and certificates of honorable mention have been awarded in each state and in the District of Columbia. The state winners entered the national contest, and it is from their essays that the six winners were selected.

The contest will be continued next year, and in addition to the prizes offered to students of high and secondary schools, which will be substantially the same as those awarded this year, six prizes of $1,000 each will be awarded to students of colleges and universities for the six best essays on the subjects designated:

"The relation of chemistry to health and disease."
"The relation of chemistry to the enrichment of life."
"The relation of chemistry to agriculture or forestry."
"The relation of chemistry to national defense."
"The relation of chemistry to the home."
"The relation of chemistry to the development of an industry or a resource of the United States."

Universities granting scholarships in addition to those provided by Mr. and Mrs. Garvan are the University of Arizona, which gives two scholarships remitting all fees; the University of Iowa, one scholarship; the University of Kentucky and the University of Mississippi, each one. In South Dakota the Northern Normal and Industrial School at Aberdeen offers a prize of $25 for the best essay submitted in the state. In Texas the Baylor College for Women offers a scholarship worth $120, and the University of Texas offers a tuition scholarship worth $120. The University of Utah has contributed a tuition scholarship, and Washington and Lee University in Virginia is offering a tuition scholarship worth $80. Both the Catholic University of America and Georgetown University will grant four-year tuition scholarships, while the University of Virginia offers a four-year scholarship to the author of the best essay submitted in that state. The University of Florida will award two one-year scholarships remitting registration and laboratory fees; Northwestern University offers one scholarship; the University of Maryland offers a tuition scholarship; St. Louis University, a four-year scholarship, including matriculation fee; and the University of Missouri has established six fellowships for the six prize-winning essays in Missouri.

PSYCHOLOGICAL RESEARCH AT YALE UNIVERSITY

AN important development of the research work in psychology at Yale, the appointment of three men of national distinction, and the gift of funds to carry on the new work are for the first time definitely announced by Yale University.

A group of research specialists will be associated together in an institute devoted to the study of fundamental problems of human behavior, and to the training of personnel for the further pursuit of new studies in the field of teaching, research and of practical application. The initiation of this enterprise is a step of the first importance toward increasing the facilities for psychological research and training. The need of such research has been increasingly felt in medicine, in industry, in education, in social work, in child welfare and in various public problems. A generous contribution for a period of five years toward this undertaking has been made by the Laura Spelman Rockefeller Memorial.

Roswell Parker Angier, professor of psychology in Yale University, will act as chairman of the group or institute, which will be an integral part of the university. It will be closely associated with the graduate school; its facilities will be available to advanced students who may be candidates for a doctorate or who may wish to engage independently in research.

Arrangements have been concluded for bringing to the institute three leading men of science. Robert M. Yerkes, formerly of the National Research Council, will have charge of the work in the field of comparative psychology with special reference to the primates; Raymond Dodge, formerly professor of psychology in Wesleyan University, in fundamental aspects of normal behavior, and Clark Wissler, of the American Museum of Natural History, in the fields of racial, and particularly primitive, human behavior in its cultural and social aspects.

SCIENTIFIC NOTES AND NEWS

AT the meeting of the British Association for the Advancement of Science, held in Toronto from August 6 to 13, general lectures were delivered as follows:

Evening discourses.

SIR THOMAS HOLLAND on "Formation and destruction of mineral deposits."

PROFESSOR D'ARCY W. THOMPSON, of St. Andrews University, on "The shell of a nautilus."

Citizens' lectures.

PROFESSOR A. S. EDDINGTON, of the University of Cambridge, on "Einstein's theory of relativity."

PROFESSOR G. H. F. NUTTALL, of the University of Cambridge, on "Cambridge."

SIR ROBERT ROBERTSON, of the Royal Arsenal, Woolwich, on "Explosives."

Lectures to children.

SIR WILLIAM BRAGG, of the University of London, on "Crystals."

L. H. DUDLEY BUXTON on "The people who live beyond the great wall of China."

PROFESSOR J. H. PRIESTLY, of the University of Leeds, on "Plant waterproofs."

THE annual meeting of the French Association for the Advancement of Science was held in Liége from July 28 to August 2, under the presidency of Professor M. Viala. This is the first time that the asso-

ciation has met outside France. The King of Belgium presided at the opening meeting, when the medal of the association was conferred upon M. Poincaré and Cardinal Mercier.

DR. WARO NAKAHARA, of the Rockefeller Institute for Medical Research, has been awarded the degree of doctor of medical science by the Imperial University of Kyoto, Japan, in recognition of his work on cancer immunity.

THE Royal College of Surgeons of England has awarded its Lister Medal for distinguished contributions to surgical science, with the honorarium of £500, to Sir W. Watson Cheyne, who, in accordance with the conditions of the trust, has undertaken to give an address at the Royal College of Surgeons next year.

THE Cagnola prize (gold medal and 2,500 lire) has been awarded by the Lombardy Academy of Sciences to Dr. E. Greppi, of Milan, for his studies on hemoglobin.

THE Leibniz Silver Medal, for 1924, of the Prussian Academy of Sciences has been awarded to Fraulein Lisa Meitner, professor of physics at the Kaiser Wilhelm Institute in Dahlem, near Berlin, in recognition of her researches on radium.

FOR the year 1924 the American Geographical Society of New York has awarded its three gold medals as follows: The Cullum Geographical Medal to Professor Jovan Cvijić, of Belgrad University, for his contributions to Balkan geography; the Charles P. Daly Medal to Colonel Claude H. Birdseye, who descended the Grand Canyon of the Colorado in the summer of 1923, in charge of a party studying the water-power possibilities of the canyon; the David Livingston Centenary Medal to Commander Frank Wild, well known for his Antarctic work.

MEDALS of the Royal Geographical Society have been awarded as follows: The Founder's Medal to Ahmed Hassanein Bey for his journey in 1923 to Kufra and Darfur; the Patron's Medal to Commander Frank Wild for his long services to Antarctic Exploration. The council have awarded the Victoria Medal to J. F. Hayford, formerly of the United States Coast and Geodetic Survey and now director of the College of Engineering of Northwestern University, for his establishment of the theory of Isostasy; the Murchison Grant to J. H. Reynolds for his work on the 1/Million Map and for the Permanent Committee on Geographical Names; the Back Grant to M. C. Lester for his geographical work in Graham Land; the Cuthbert Peek Grant to F. Kingdon Ward to assist him in his present journey in Tibet; the Gill Memorial to Major A. L. Holt for his surveys in Arabia.

AT the annual general meeting of the Faraday Society, held on July 7, in London, Professor F. G. Donnen was elected to succeed Sir Robert Robertson as president.

PROFESSOR MICHAEL I. PUPIN and Dean George B. Pegram, of the Schools of Mines, Engineering and Chemistry, have been designated to represent Columbia University at the centenary of the Franklin Institute, Philadelphia, September 17 to 19.

PROFESSOR VLADIMIR KARAPETOFF, of the school of electrical engineering at Cornell University, has been nominated on the Socialists' New York State ticket for the office of state engineer and surveyor. Two years ago the late Dr. Steinmetz was the socialist party's nominee for the same office.

D. B. Dow, of the Petroleum Experiment Station of the Bureau of Mines, has been appointed engineer in charge at the new station now being established at the University of Wyoming.

HENRY C. BERGER has resigned from the research staff of the U. S. Bureau of Mines to take the position of research chemist for the Armstrong Cork and Insulation Company, New Jersey.

DR. R. E. M. WHEELER has been appointed director of the National Museum of Wales, in succession to Dr. William Evans Hoyle, who resigned the position recently owing to ill health.

DR. C. V. PIPER, of the United States Department of Agriculture, who has been studying pastures and meadows in Europe, returned in the latter part of July.

THE orator at the University of Chicago, at the convocation on August 20, will be Professor John Merle Coulter, head of the department of botany at the university, whose subject is "The international mission of universities."

A BUST of the late Professor Blanchard, the parasitologist and authority on tropical medicine, has recently been unveiled at his birthplace, Saint-Christophe, in Touraine.

THE Société d'Anthropologie of Paris recently celebrated the centenary of the birth of Paule Broca, who founded the society in 1859.

THE death is announced of Dr. David Lobo, emeritus professor of obstetrics and rector of the Central University of Venezuela, recently president of the National Academy of Medicine.

DR. FILIP POČTA, professor of paleontology and geology at the University of Prague, died recently at the age of sixty-five years.

THE death is also announced of M. Emile Pierard,

of Brussels, president of the Société Belge des Electriciens, and an authority on the subject of electric transmission lines.

THE Commission on Standardization of Biological Stains is at work preparing a book on stains, dealing with their chemistry, synonymy and uses, discussing the characteristics of satisfactory and unsatisfactory stains. At present the chairman of the commission, H. J. Conn, is on leave of absence from the New York Agricultural Experiment Station in order to collect data for this book. It is hoped to have it ready for publication some time during the coming winter.

THE date for the summer meeting of the American Ceramic Society has been set for October 6 and 7, at the Hotel Biltmore, Los Angeles, California. The morning and afternoon sessions will be devoted to the reading of papers and discussions. The dinner meeting will be on Tuesday evening. Railroad excursion rates will be granted with the usual stop-over privileges. For further information communicate with either Mr. Fred B. Ortman, chairman of the Summer Meeting, Tropico Potteries, Inc., Glendale, Calif., or with the general secretary, Lord Hall, Ohio State University, Columbus, Ohio.

ACCORDING to *Chemical and Metallurgical Engineering,* the International Union of Pure and Applied Chemistry has been invited to hold its 1926 meeting in the United States in conjunction with the fiftieth anniversary meeting of the American Chemical Society. Those of the members of the International Union who have been consulted in connection with the proposal say that the only objection is the expense, although it is admitted that many members of that organization would be willing to expend a reasonable amount for the education and experience that would result from it. Officials of the American Chemical Society now are conferring with the railroads to see what special rates may be obtainable for a special train which would convey the visitors, during their stay, to the principal centers of the chemical industry. It is believed such a plan, which would permit of their living on the train, would reduce the expense materially.

AN International Conference on Health Problems in Tropical America was held at Kingston, Jamaica, from July 23 to 31.

THE 1924 session of the Institut International d'Anthropologie will be held this year in Prague, Czechoslovakia, from September 14 to 21. The session will be held under the auspices of the Czechoslovak government and includes excursions to the famous caves and localities of ancient man in Moravia. To facilitate attendance, passport visa for members of the congress will be dispensed with, and a 50 per cent. reduction will be allowed for members and their families on all the railroads within the Republic. The congress will be devoted to all branches of anthropology and communications may be presented in any of the modern languages.

WE learn from *Nature* that the international Commission on Illumination held its sixth session at Geneva from July 21 to 25, under the presidency of Dr. E. P. Hyde. Twenty-six papers on subjects connected with illumination were presented, and delegates from America, France, Great Britain, Italy, Japan, Poland and Switzerland were present. The papers dealt with photometric nomenclature, primary standards of light, heterochromatic photometry, automobile and industrial lighting and legislation. As a result of the discussions, progress was made on a number of problems in which international agreement and cooperation is desirable.

THE twenty-third Flemish Congress of Natural Science and Medicine was held at Aalst on August 9 and 10.

THE Belgian Society of Hydrology will hold the next congress at Brussels, under the chairmanship of Dr. Modeste Terwagne, from October 15 to 17, 1925.

THE Department of Biology and Public Health at the Massachusetts Institute of Technology, beginning with the next college year, will offer the degree of doctor of public health to properly qualified candidates. The new degree will be placed on the same level as the degrees of doctor of philosophy and doctor of science, requiring, in general, at least three years of graduate work for those possessing the bachelor's degree.

A JAPAN Eugenics Society has been organized under the management of R. Goto. A monthly magazine, of which the English part of the title is *Eugenics,* is being published to spread the knowledge of eugenics in Japan.

THE Bureau of Mines radium laboratory has been set up in Washington after its transfer from Reno. This change in the location of the laboratory was made so that the work could be under the personal supervision of Dr. S. C. Lind, the bureau's chief chemist.

WORK has been begun by the Wisconsin Committee on the Application of Electricity to Agriculture, of which Dean H. L. Russell, of the College of Agriculture, is chairman. The experimental community selected is situated southwest of Ripon, starting near the city limits and extending out about six miles. About fifteen general farmers and two pea viners will have their farms electrified and studied. Accurate records on the use of all electrical equipment and specially made farm machinery will be kept and the results will be broadcast throughout the state.

It is believed the community will be visited by many thousands of farmers during the course of the experiments, which will be continued for more than a year. The high-voltage power line which will serve the farm electric laboratory is about completed, and within a very short time the farmhouses and barns will be wired for service.

ACCORDING to *Chemical and Metallurgical Engineering,* an appropriation of $90,000 will be asked of the Congress next December by the Bureau of Mines, for the purpose of establishing a plant in the field for the extraction of oil from shale, on which for several years the bureau has been engaged in laboratory experimentation. The estimate for this appropriation was submitted to the budget bureau several weeks ago and has been approved by General Lord, director of the budget, and by President Coolidge. The appropriation is to cover the construction of the plant, the land necessary for the plant and the securing, by purchase or otherwise, of the necessary shale or shale land.

SECRETARY OF THE INTERIOR WORK has recently taken steps to formulate a committee composed of representatives of the American Bar Association and leading patent bar associations of the country to simplify methods of procedure and expedite the business of the Patent Office. The plan of Secretary Work is to have the committee after its organization make a thorough review of the Patent Office and to submit suggestions for changes in methods that should result in bringing the work of the bureau to a current basis in the near future. Because of a tremendous increase in the patent business during the last few years, the Patent Office has been unable to keep up with the number of applications for patents that have been filed by the public.

ACCORDING to the scientific correspondent of the London *Times,* two Dutch investigators, Professors Paul Frosch and H. Dahmen, have succeeded in isolating the virus of foot-and-mouth disease, the virulent contagious malady of cattle which in recent years has threatened economic disaster to the stock-raising industry. It has long been accepted that the causative agent of this plague must be a living organism capable of surviving outside the body of cattle for a sufficient time to spread by unknown ways. The Dutch professors now have not only isolated the virus, but have been able to make pure cultures of it on solid media. Thus the first stage towards conquest of the disease has been reached. The method they have employed has been the use of the ultra-microscope and the taking of photographs by light-rays beyond the range of visibility.

ON July 1 the metric system became the official standard of measurement in Japan and was so announced in a recent imperial ordinance, according to advices to the Department of Commerce. The government for some time has been conducting an educational campaign in order to popularize the system and has staged demonstrations in various cities. The law does not contemplate the immediate universal use of metric units, since it is realized that it will require considerable time to overcome the numerous difficulties. The great majority of the Japanese people understand only the native units and are very conservative and prone to stick to old customs and habits. Furthermore, there are very formidable physical and financial difficulties to overcome. The replacement of the present scales used by the Imperial government railways, for example, will mean the purchase of several thousand new scales at an expenditure of possibly 1,000,000 yen.

The Medical Journal and Record states that, at the British Empire Exhibition now being held at Wembley, in London, there is a Tropical Health Department which is intended to give a graphic representation of the various diseases and to explain how they are caused and how they may be prevented. The disease section deals with twenty-seven diseases, and one portion is given over to those which are spread by biting insects. Photographs, pictures, models and specimens are employed to describe each disease, and a brief history and the existing means for fighting it are also given. Among these diseases are included such conditions as malaria and yellow fever. Another group includes those due to intestinal infection such as typhoid fever. Food deficiency diseases are represented by scurvy and beriberi. Much space is devoted to skin diseases, yaws and leprosy. The third section deals with hygiene and the fourth with plant diseases.

ACCORDING to the *Journal* of the American Medical Association the public-health committee of the New York Academy of Medicine has been making a survey in this city as regards the care of convalescent patients. A special report which this body has made on this "neglected phase of medicine" points out that there has been no serious discussion of the kind of care which the various types of convalescent patients require. There has likewise been no thorough consideration of the types of cases which should be cared for jointly, and which would harmonize from an administrative medical point of view. To remedy this the public health committee plans to study the convalescent needs of the city, with a special view to the framing of a community policy and developing medical and administrative standards for the guidance of convalescent homes. It plans to organize a central reference bureau to furnish information and to act as a clearing house, to facilitate a better distribution

of convalescent patients to the existing homes and hospitals, and to assure treatment best suited to each patient. The bureau will be financed by the Sturgis Research Fund and the Burke Foundation. The survey shows that the existing facilities are reasonably sufficient but that they are underutilized.

ACCORDING to *Nature*, arrangements have been made to establish at Oxford in October next the Imperial Forestry Institute, which is intended to serve as an educational and research center for the British Empire. It will be a university institution, with the professor of forestry as its director; but it will be under the control of a board of governors, with a forestry commissioner as chairman. The educational work of the institute will comprise (1) post-graduate training of forest service probationers and other qualified persons, (2) training of research officers in special subjects, and (3) provision of courses for selected officers already serving. The institute will be open to various categories of students, who must as a rule have had previous training at a university in forestry or some allied science. The normal course of study will extend over one academic year, and the subjects dealt with will cover the whole range of forestry.

NEW experimental equipment produced at the Cruft laboratories of Harvard University is being installed in a large DeHaviland plane for the purpose of dispersing fog or clouds. This includes sand boxes on each side of the fuselage, which are connected to batteries. By pulling a lever the electrified sand is released through a nozzle and sprayed over the cloud or fog bank which is to be exterminated.

THE *British Medical Journal* states that the reports on serological investigations presented to the Second International Conference on the standardization of sera and serological tests held at the Pasteur Institute in Paris in November, 1922, have been published in a volume of some 300 pages by the health organization of the League of Nations. The reports deal with the standardization of serums for diphtheria, tetanus, meningitis, pneumonia and dysentery, and with the sero-diagnosis of syphilis.

FOR the preservation of the only two herds of wood bison known to exist in a wild state, the Canadian government has set aside an area of five thousand square miles in the wilderness south of Great Slave Lake. Little has been known of these herds of wild wood bison until a party was sent out by the Canadian government in 1922 to get all available information. It was then learned that the number of bison in the northern herd is at least five hundred with twice as many in the southern herd.

A 26-INCH refracting telescope is to be installed at Johannesburg, South Africa, by Yale University, according to a report from Consul G. K. Donald to the Secretary of State. Yale's decision on the location of the telescope was largely due to the American Chamber of Commerce at Johannesburg. At its request, the minister of railways granted a 15 per cent. reduction in freight rates from the coast, the commissioner of customs and excise has promised to request from parliament free entry for the telescope and accessories, and the director of the union observatory at Johannesburg, besides affording the facilities of astronomical time service, dark rooms, etc., has promised a free site in its 15-acre reservation.

A FURTHER stage in the development of the Cast Iron Research Association was reached a few days ago, when the association formally took possession of its laboratories. These are situated in Guidford Street, Birmingham, and are equipped for the conduct of chemical analyses and general metallurgical and heat-treatment work. The capacity of the association to deal with its work will be greatly increased, but it is not intended to abandon the policy of having investigations conducted in prominent university laboratories and in the works of members. It is anticipated that the association, which commenced a new financial year on July 1, will incur an expenditure during the year of between £6,000 and £7,000. The research program includes important investigations on erosion- and corrosion-resisting cast irons; moulding sands; graphitization; heat-resisting cast iron; the production of malleable cast iron; cupola practice; cast irons for electrical and magnetic purposes; measurement of melting and pouring temperatures; the fundamental properties of cast iron; standardization of test bars, materials and methods; facing sands and blackings; cast iron to resist abrasive wear, and, jointly with the British Motor and Allied Manufacturers' Research Association, automobile cylinders and pistons.

UNIVERSITY AND EDUCATIONAL NOTES

THE Carnegie Corporation of New York has paid to Samuel H. Church, president of the Carnegie Institute of Pittsburgh, $8,000,000 provisionally promised four years ago, to be added to the endowment for the educational work of the institute. This makes the total amount given to the Carnegie Institute by Mr. Carnegie and the Carnegie Corporation $38,000,000.

IN connection with the incorporation of Rush Medical College as a part of the University of Chicago, the medical work on the quadrangles of the university has been organized under the name of the Graduate

School of Medicine. To emphasize and assure the scientific character of this school, it is not organized separately from the Ogden Graduate School of Science, but within that school as a part of it.

IT was stated in SCIENCE that Dr. A. Ross Hill had been elected president of the University of Oklahoma. Dr. Hill was offered the presidency some time ago, but was unable to accept. Dr. J. S. Buchanan, acting president since the resignation of Dr. Stratton D. Brooks to accept the presidency of the University of Missouri, was elected president at the meeting of the Board of Regents held on June 3.

C. M. CARSON, director of the department of chemistry, has been appointed acting president of the Michigan College of Mines, to succeed the late Dr. F. W. McNair.

N. HENRY BLACK, of the Roxbury Latin School, Boston, has been appointed assistant professor in Harvard University to teach physics and to organize courses on science teaching in the Graduate School of Education.

DR. R. B. STREETS, of the University of Wisconsin, has been appointed assistant professor of plant pathology at the University of Arizona.

DR. IVAN C. HALL, of the University of California, has been appointed professor of bacteriology at Cornell University, Ithaca.

DR. P. W. WHITING, research associate professor of eugenics, of the Iowa Child Welfare Research Station, has resigned to become professor of biology at the University of Maine.

E. A. MILNE, assistant director of the Solar Physics Observatory at Cambridge, has been appointed to the Beyer chair of applied mathematics at the University of Manchester.

DISCUSSION AND CORRESPONDENCE

THE USE OF SEA SALINES IN THE TREATMENT OF GLANDULAR (INCLUDING UNDOUBTEDLY GOITROUS) ENLARGEMENTS—HISTORICAL NOTES

IN a previous discussion upon the relationship between the purity of our dietary condiment known as "common salt" or "table salt" and the existence of endemic goiter, the writer believes he was the first one to draw attention (see this Journal, LIV, No. 1389, p. 131, August 12, 1921) to the significance of the geochemic phenomenon by which iodine has been largely leached from the soil of many localities and to the significance of the source of our present-day article, derived, as it is practically altogether, from inland deposits and brines rather than from sea water and "alkali" mineral springs, as was the former-day custom. I also pointed out the possible desirability of using a condiment consisting of total sea salts or even sea water in place of our table salt. The full results of my inquiries in this direction were published in the *Jour. Am. Med. Assoc.*, Vol. 78, 18–21, Jan. 7, 1922.

In the spring of 1922, Professor Raymond C. Osburn gave me an interesting reference from "Buckland's Log Book of a Fisherman and Zoologist," London, 1883, p. 161, to wit:

> Just one hundred and twenty years ago a very small but very remarkable book was published. The title of it was "A dissertation on the use of sea water in the diseases of the glands, particularly the scurvy, jaundice, king's evil, leprosy and the glandular consumption," translated from the Latin of Richard Russell, M.D., by an eminent physician. "The sea washes away all the evils of mankind," *Eurip., Iphig. in Taur.*, v. 1193. London: Printed at Homer's Head, Temple Bar; and R. Goadby at Sherbourne, 1752.

It has appeared to me that some excerpts from Russell's book, necessarily unscientific as they are, might prove of interest, both historically and otherwise at the present time, especially in regard to the use of sea foods and sea salt in the preventive treatment of endemic adolescent goiter and perhaps other "deficiency diseases" which were, of course, unrecognized as such in his day.

Russell's original work was entitled *"De tabe glandulari, sive de usu aquae marine in morbis glandularum dissertatio;" 3 p. l.*, 3–235 pp., 7 pl. 8° (oxoniae). *J. Fletcher et J. et J. Riverton*, 1750. At least four editions of this work, translated into English, appeared under dates as follows: 1752, 1753, 1760 and 1769. The edition of 1753 reached 398 pages. That of 1760 contained also "A translation of Dr. Speed's commentary on Sea Water." The following are taken from the 3rd English edition (1760):

> By sea water joined with other medicines, the Glands may be successfully purged, and freed from Obstruction —p. 7.
>
> The Patient will bear the Stimulus of the Sea water six months and, in Disease of Skin, I have known a Patient bear it tolerably well for a whole year. * * * But Sea Water will heal many Diseases where Mercury is of no service—page 8–9.
>
> Drink a pint of Sea water next A. M., (for gonorrhoea)—p. 61.
>
> [Dr. Speed] As the Use of Sea Water has grown in Fashion * * * I determined to try Experiments on the waters that washed the shores of that County [Hampshire]—p. 145.
>
> The Ancients were very cautious in giving it inter-

nally and Dioscorides (*Med. Mater., lib. V, cap. 23*) acknowledges sea water was given internally as a purge by itself. He recommended: Equal parts of Honey, Sea and Rain Water: also Wine made with sea water to purge the body, also to relieve those who spit purulent matter, and those that are costive. * * * In *de Parabilibus,* he affirms that sea water drank with Oxymell will break internal abscesses.—p. 150.

Half a pint of Sea Water drank at night going to Bed repeated in the Morning, is generally enough for Adults—p. 153.

For the glands of King's evil—operate and use Sea Water both internally and externally (as embrocations). [Many case reports given]—p. 156.

From what has been said it will appear that this method of cure is no invention of the Moderns, but was known to the Father of Medicine while it was in its infancy—p. 171.

It would appear, therefore, that the idea of using sea water or sea salts for medicinal and health purposes was a custom well established in former times, but one which a careful examination of medical and health literature of the present day shows has been quite discarded (in favor of "purified products"). Instead of the "old fashioned salt" derived by evaporation of sea water and retaining a trace or more of the thirty-odd elements said to be present in sea water, entirely new and also far cheaper source-methods of salt supply (from mines and brines of inland sources) is now the plan, and as a result we have a purified article, *sodium chloride.* Thus, as I have suggested in my previous articles, we have possibly created a condition of iodine and other elemental starvation purely by our commercial procedures. Should we not pursue a "back to nature" plan in this matter, as is advocated in connection with some of our vitamin-free food articles? Necessarily more scientific investigation is still essential to substantiate this, but observational evidence on all sides is strongly in support of it.

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THE CURE AND PREVENTION OF EAR CANKER IN RABBITS

ONE of the many serious chronic diseases of rabbits that may interfere with the use of this animal in laboratory work is "ear canker." This disease may seriously handicap or cripple research, especially experiments requiring months or years of observation on the same animals.

Ear canker is caused by an animal parasite (*Psoroptes cuniculi*) which closely resembles the mite (*Sarcoptes cuniculi*) causing scabies. Curiously, it attacks only the concha of the ear. The earliest manifestations of infection are indicated by hyperemia and the formation of reddish brown crusts near the bottom of the concha. The hyperemia and crust formation extend and after months may involve nearly all the inner surface of the ear. The most serious complication of the disease is pyogenic infection of the middle ear which may extend to the internal ear and meninges. The parasite spreads more rapidly during the warm months. The disease is widespread, and few, if any, laboratories escape its occasional introduction.

The usual methods prescribed for treatment involve isolation and are elaborate and costly. For many years we have been treating the infection in important animals by the time-honored plan of removing the crusts and swabbing the concha with glycerine containing 2 per cent. carbolic acid. This method, as with many others of the same type, is tedious and time consuming. Last June (1923) when the laboratory was heavily stocked an extensive outbreak occurred, both in the old and the young stock. In casting about for some quick means of attack, we decided to try kerosene on account of its powerful insecticidal action. This was sprayed into the ear with a small De Vilbiss atomizer. Each ear received the amount of kerosene spray discharged from three or four compressions of the bulb or sufficient to moisten only the inner surface of the ear. The ears were sprayed twice, with an interval of six days. At the end of two weeks all the rabbits were cured of the infection and no case has since developed in our rabbit colony, averaging about 200 animals. It is doubtful whether the second spraying was necessary.

We have been prompted to call the attention of other laboratory workers to this well-known infection for the following reasons: (1) This experience was one of the most striking therapeutic effects in mammals we have ever witnessed; (2) Kerosene spray affords a specific, cheap, simple, rapid and certain means, both of curing and preventing the disease.

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THE MEANING OF CONSERVATION

IN an article entitled "Two kinds of conservation," published in *The Scientific Monthly* for March, 1924, Dr. E. E. Slosson makes a statement which, in my opinion, is likely to help to perpetuate an old misconception of the meaning of conservation as applied to natural resources—a misconception which Dr. Slosson probably does not share. The likelihood is increased by the fact that the statement is strikingly clear and forceful—as is usual with what Dr. Slosson says—and is almost but not quite correct.

Dr. Slosson says, "The conservation of oil means not using it, for all the oil that is used is forever lost.

The conservation of water power means using it, for all the water power that is not used is forever lost." The first eight words of the statement could be used by anti-conservationists in opposing conservation activities on the grounds that the latter require the present generation to suffer for the benefit of future generations. Regardless of the moral status of such a requirement, it is practically certain that no "present generation" would submit to it.

For fifteen or twenty years, America's most effective conservationist, Mr. Gifford Pinchot, has found it necessary to disabuse people's minds of the misconception that conservation means disuse. As recently as May 17, 1924, in an article in the *Saturday Evening Post*, Mr. Pinchot said:

> Let no man persuade you that conservation and stagnation are the same. From the beginning conservation has meant wise use in the public interest, and it means wise use to-day. This generation has a right to all it needs, but no right whatever to waste what it does not need. Our children have their rights as well as we. If there was ever a policy since this world began that was simple, sound and filled with common sense, it is the policy of conservation.

Mr. Pinchot explains in the same article that the oil deposits *in the national reserves* need not be exploited now. The reason obviously is that the oil in them is not now needed. But conservation should include privately owned as well as publicly owned oil deposits, just as it should include privately owned forests. Private oil properties are sufficient for present needs and as Pinchot says, "This generation has a right to all it needs, but no right whatever to waste what it does not need."

As a definition of conservation, Dr. Slosson quotes from Acheson: "Conservation consists in the utilization of the inexhaustible for the preservation of the exhaustible." This sounds attractive and it perhaps describes a laudable ultimate ideal. But for economic, physical or other reasons, its practical application is impossible in meeting many of our greatest and most urgent needs, with the knowledge now available. In my opinion a more workable though rougher definition which is readily inferred from the writings of Roosevelt, Pinchot and other great conservationists is, "Use without waste and, wherever possible, with replacement."

The great problem in the conservation of exhaustible resources is to find and to apply feasible methods of increasing the efficiency of utilization, which is about the same as saying to find and to apply feasible methods of reducing waste.

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THE eight words of mine that Dean Farrell criticizes, "The conservation of oil means not using it," are literally true, yet I did not intend them to be taken literally. To keep the oil in the earth would indeed conserve it—if nobody tapped the pool—but it might better have been used up than to remain forever unused.

I am reminded of the poor woman whom a philanthropic visitor found in the slums. She had five small children and one at the breast; her husband had broken his leg; she was out of food and fuel and was about to be evicted from the flat for non-payment of rent. Yet she boasted of having five hundred dollars in the savings bank and when the visitor asked why she did not draw out some of it she replied that she was "saving it for a rainy day."

I really did not anticipate that any reader of *The Scientific Monthly* would suspect me of advocating such an extreme form of conservation. And I hasten to add—lest I be called before the Senate Investigating Committee—that I was not talking about oil especially, but discussing the general principle of conservation applicable to coal, certain metals and minerals, and any other natural resources that are limited and irreplaceable.

Yet I may confess that I believe the day is coming —and I hope to live long enough to see it—when it will be wise to prohibit the burning of petroleum and natural gas because they will be found indispensable as material for the manufacture of organic compounds, possibly even food since edible fats have been made from petroleum. If that be treason, make the most of it.

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MR. W. E. MYER'S ARCHEOLOGICAL COLLECTION

THE late W. E. Myer, of Tennessee, served as volunteer assistant in the Bureau of Ethnology for several years. For about forty years he had made studies of the archeology of the Tennessee and Cumberland river valleys. Dr. J. Walter Fewkes, head of the bureau, told me last May that the bureau had lost a most efficient and valuable worker. Myer was one of the few men in the United States who was familiar with prehistoric cultures throughout the main Mississippi valley. He has left an important work in manuscript form embodying detailed studies in Tennessee archeology.

Up to the time of Mr. Myer's connection with the bureau, he carried on extensive researches at his own expense. He very carefully recorded all specimens

found. He left his heirs some 15,000 or more stone, bone, shell, clay and copper artifacts of aboriginal workmanship. These include many interesting engraved shells, decorated copper plates, effigy pipes, etc. It is doubtful whether Myer's collection could be duplicated in the state of Tennessee, since most of the monuments and graves have been explored.

The heirs wish to have Mr. Myer's collection preserved intact in some museum. It has been highly recommended by Dr. Neil M. Judd, of the Smithsonian, Dr. Fewkes and others. Mr. Myer's son, Mr. W. H. Myer, care of Frazer & Co., 30 Church Street, New York, N. Y., has the matter in charge and will be glad to correspond with any museum officials who are interested.

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SCIENTIFIC BOOKS

Illustrated Flora of the Pacific States, Washington, Oregon and California. By LEROY ABRAMS. Vol. 1. Stanford University, California, Stanford University Press, 1923. xii + 557 pp. $9.00, prepaid.

A DESCRIPTIVE flora is primarily for the purpose of enabling one to identify the plants of the region covered. But some go farther than this and aim to give also new information regarding the plants themselves. Professor Abrams' flora is distinctly a work of this latter sort and is to be classed as a valuable contribution to knowledge of the morphology, relationships and geographic distribution of the species growing spontaneously in the three Pacific Coast states. The flora of this region has been so little studied, as compared with that of other parts of the United States, that numerous readjustments in the classification are necessary if an author is to present anything more than a compilation of previously recorded facts, and in the present instance his intimate field acquaintance with the flora and his access to types in eastern and European herbaria have enabled him to prepare what is essentially a critical revision of each of the genera treated.

But this assembling of new material has not been permitted to interfere with the more immediately practical values of the book. The style and general make-up are frankly patterned after the well-known illustrated Flora of the Northern United States and Canada, by Britton and Brown. Consequently, each species is illustrated by a text figure as well as keyed and described and the distribution and principal synonyms are clearly given. It is confidently predicted that, as in the case of its prototype, the figures will greatly add to the popularity of the work and that many users who would otherwise prefer a more conservative treatment of genera and species will b led to adopt the accompanying names.

In the matter of generic and specific concepts, th author has not gone to the extreme in either direc tion, although there is a decided tendency toward the acceptance of generic segregates and "sma species." The nomenclature follows the rules no under consideration by the American Botanical So ciety and recommended by its nomenclature commi tee (of which Professor Abrams is a member). Ther is here a splendid opportunity for comparing th results with those obtained when the International Code and a more conservative treatment of genera and species are followed, for Professor W. L. Jep son, who in the main follows the latter code an who is moderately conservative, has recently covere most of the same area and the same families in hi "Flora of California." Since much of this firs volume of the Abrams flora has been contributed b collaborators, some of whom also contributed to th Jepson flora, it is necessary to select for comparis some portion of each book prepared by the autho himself. Consequently the Liliales and Orchidale have been chosen as furnishing a fair comparison and all non-Californian forms have been excluded since these are not covered by Professor Jepson' work. In the two orders named, Abrams gives families, 57 genera and 255 species, whereas Jepso has 5 families, 45 genera and 225 species. Further more, there are 55 additional cases where the plan names differ, although the authors are in agreemen as to specific limits. The final result is that if on were to use Abrams's flora and then turn to Jepson' he would find that of the 255 plant names accepte in these orders by the former, only 170, or about 6 per cent., are given full recognition by the latte The remaining 85 names, or 33 per cent., would nee to be sought among the synonyms and a considerab number could not be found even there.

In attempting to discover the reasons for thes differences, it develops that 29 per cent. of the case of non-agreement are traceable to differences in th rules of nomenclature followed by the respectiv authors, while 71 per cent. are due to differences o opinion as to what constitutes genera and species It seems, therefore, that an agreement among taxono mists as to rules of nomenclature, although muc to be desired, is perhaps only secondary in import ance as compared with the need of an agreement o generic and specific limits.

On analyzing the situation farther, it is found that, at least as between these two authorities, th shifting of generic lines is responsible for as many name changes as is the difference in species concept What an enormous amount of confusion would b avoided if all systematists were to apply the princip

of leaving established genera intact, except in those instances where they are composed of unnatural assemblages of species. Such procedure has been especially advocated by Dr. Robinson.[1] What a saving of energy this would mean—energy that could then be applied to the fundamental problems of plant classification! It may here be noted that this shuttling back and forth of botanical names is not science and that time spent upon it might well be given to the real problem of the taxonomist, namely, the determination of relationships, or, in other words, the construction of a natural classification based upon phylogeny and supported by evidence from every possible source, including experiment, statistics and the paleontologic record.

In putting out a flora of this sort, the author often encounters forms which are not of sufficient value to be ranked as species but which are, nevertheless, too important to be entirely ignored or to be relegated to synonymy. Professor Abrams has wisely adopted the expedient of assembling some of these under those species of which they are evolutionary derivatives and of printing the name and the brief description in small type. By this method the user of the book is permitted a choice between the segregate name and the one given for the inclusive species. It is quite probable that for some purposes the one will be the more useful, while in other connections the alternate name will be chosen. In the reviewer's opinion, the book would find a far wider field of usefulness if the accepted species were made much more inclusive and more advantage taken of the subordinate category. By this means the number of full species would be considerably reduced, an outcome much desired by the non-specialist, and the segregate names would still be available for those who might find use for them. If, in addition, the more important of these latter were to be treated as subspecies or varieties their relationships to the parent stock would be immediately evident in the trinomial used for their designation. Under this procedure only the limits of the collective species would need to be agreed upon while the minor categories could be modified to meet special needs without disturbing the binomial. It is evident that some such plastic arrangement must be worked out if botanical nomenclature is to attain its fullest value.

The first volume of this important flora, which is to be completed through the issuance of two more, begins with the *Ophioglossaceae* and ends with the *Aristolochiaceae*. It thus includes all the ferns and fern allies, the gymnosperms, the monocotyledons and most of the apetalous families of the dicotyledons. Portions of the text were supplied by specialists, as follows: *Pteridophyta* (except *Isoetaceae*) by William R. Maxson, *Isoetaceae* by Dr. Norma Pfeiffer, *Poaceae* by Professor A. S. Hitchcock, *Cyperaceae* (except *Carex*) by Dr. N. L. Britton, *Carex* by Mr. K. K. Mackenzie, and *Salix* by Dr. C. R. Ball. Dr. F. V. Coville assisted in preparing the text of the *Juncaceae*. In matters of typography, illustration, index, etc., the book is all that can be asked for. It is hoped that the succeeding volumes will appear as rapidly as the painstaking methods of the author will permit.

HARVEY M. HALL

[1] Robinson, B. L., 1906, SCIENCE, N.S., Vol. 23, pp. 81–92.

LABORATORY APPARATUS AND METHODS

A MODIFICATION OF RECONSTRUCTION METHODS

AFTER reconstructing several chondrocrania models of beeswax, which proved to be a laborious task, the writer has succeeded in perfecting a method that eliminates the unpleasant but necessary details of making the plates which are required in the older methods where wax is used, and at the same time shortened the process of construction without sacrificing accuracy.

This method differs from that described by Sussana P. Gage ('07), in the *Anatomical Record*, Vol. I, page 166; in that strawboard is used instead of blotting paper, and beeswax in the place of pins and nails, as the principal substance for fastening the sections together. Wire is necessary as an additional support only in the larger models where special stress occurs.

Strawboard is considered preferable to blotting paper where the sections are cut fifteen micra or more, as it may be obtained in practically any desired thickness at almost any print shop, thus avoiding the necessity of two or more thicknesses to represent each section, as may occur where blotting paper is used. Strawboard is more firm than blotting paper and is considered by the writer to be less easily distorted. Standard grade number 40, which is approximately two millimeters in thickness, has been used with satisfactory results in the construction of several models, which vary from four to seventeen inches in length. Camera lucida outline drawings of the parts to be modeled are made on the strawboard and a sewing machine is employed to make a perforated pattern of the drawn parts with the needle of the machine piercing the holes close enough together that separation along the lines may be practically complete. The pieces cut out, however, usually retain their position, until intentionally removed. Before each piece is placed in the model,

the part on which it is to rest is given a thin uniform coating of melted beeswax, then the new part is added, pressed down and held in position for a short time until the wax hardens. After the model is thus built up the exposed surfaces are covered with a thin coating of wax, which on hardening smooths the surface and tends to prevent injury from excess moisture.

One objection to reconstructions made entirely of wax is that they are very apt to become distorted when exposed to the variable temperature of an ordinary room. Models constructed as described above are not so easily affected, since the beeswax between the strawboard sections is protected. Such models are also lighter, easier to handle, and not so liable to injury when packed and shipped as are the wax ones. In this respect they differ little from those made of blotting paper. The greatest advantage over both the wax and blotting paper methods is the rapidity with which a reconstruction can be made, without the sacrifice of accuracy. The fact that the blanks are easily preserved makes possible their use at a later time in checking over the details of the model, which often is of great assistance.

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INEXPENSIVE LANTERN SLIDES FOR TEXT OR TABULAR DATA

It is often desirable to project text, mathematical formula or tabular data upon a screen for purposes of class instruction or during the presentation of a paper at a scientific meeting. Use of a lantern saves the time of the instructor which would be necessary to inscribe the data on a blackboard and also makes for greater accuracy and legibility. The obvious drawback to the use of the lantern lies in the cost of photographed lantern slides.

I have found that very satisfactory slides may be prepared by making use of the ordinary "Dermatype" stencil sheets such as are used for mimeograph work. The data are cut on this stencil by the bare type of a typewriter so as to occupy an area on the stencil measuring approximately 7 x 8.5 cm. By the use of elite type, rather extensive tables can be printed within this space. A portion of the sheet, with the data in the center, measuring 8.5 x 10 cm, is then cut from the stencil by a sharp knife or a safety razor blade and mounted between two thin sheets of glass of the same dimension. Black paper tape is later used to bind the edges of the glass.

Such a lantern slide projects light figures or letters on a light blue background, the data being plainly visible even in a fairly well-lighted room.

Such lantern slides are permanent and can be prepared at a cost for materials of approximately five cents each.

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SPECIAL ARTICLES

SPECIFICITY IN FERTILIZATION

The results of experiments that I completed while working as a research associate of the Carnegie Institution of Washington, at the Misaki Marine Biological Station of Tokyo Imperial University, add to our knowledge of the factors controlling specificity in fertilization.

The methods devised made it possible to eliminate cortical block to activation in every cross-activation attempted, and to obtain better than 90 per cent. early development in all cross-activated material. This percentage of cross-activation is unusually high, but the especial significance of the results lies in the fact that of thirteen cross-activations made, eight were from four pairs of reciprocal crosses. It is well known that the facility with which a cross-activation is made in one direction is no indication of the degree of success which may be anticipated with the reciprocal cross.

All the work was done with echinoids. The preliminary studies of species fertilization revealed the fact that the eggs of *Heliocidaris tuberculata* did not form a separated fertilization membrane, and that the eggs of *Temnopleurus toreumaticus*, shortly after insemination, contracted strongly within the fertilization membrane, not to resume their normal rounded form until just prior to the first division.

We think of developmental reactions in terms of eggs. Ordinarily, we endeavor to give the egg such treatment that it will follow its own normal course of development. These experiments followed a different plan. I decided to inseminate the *Heliocidaris* egg with *Temnopleurus* sperm and then attempt to make this egg show the reactions that are normally shown by the *Temnopleurus* egg following species activation, namely, to form a separated fertilization membrane and to contract strongly a few minutes after activation.

To state the matter in another way: After some comparative study I took as a working hypothesis the idea that sperms differ in degree, at least, in their effect on the egg. The effect produced by a spermatozoön on the egg of its own species may be called, for convenience, its natural effect. The work done by a spermatozoön in producing the natural effect is an indication of the natural potency of the spermatozoön.

Proceeding on the idea of using sperms as units of an *activating substance,* the plan of supplementing the natural potency of a spermatozoön by increasing or by diminishing its task was tried. A spermatozoön was regarded as having a definite amount of energy, an amount which might be sufficient, or too much, or not enough to produce the effect desired, and which, therefore, may be used as it is, or its task made more difficult or easier, as the occasion demands. In other words, it was decided to grade the spermatozoa to different degrees of activation by indirect means. What really was done was to grade eggs to the natural potency of the spermatozoön.

Seven cross-activations of the egg of *Heliocidaris tuberculata* were made. In no two of these was the necessary treatment of the egg the same. *Heliocidaris* eggs accept species activation readily in unmodified sea water; they must be treated with solutions that are regarded as increasing their permeability before they can be activated by, *e.g., Temnopleurus* sperms; while they must be treated with solutions that are regarded as decreasing their permeability, before they can be activated by, *e.g., Astriclypeus* sperms.

Heliocidaris and *Temnopleurus* are both regular echinoids. They belong to different families of the same sub-order. A cross between them is therefore of inter-family width. *Astriclypeus manni* is a Clypeastroid. A cross between *Astriclypeus* and *Heliocidaris* is therefore inter-ordinal.

HELIOCIDARIS ♀ × TEMNOPLEURUS ♂

For this cross-activation the following method was used:

(1) Eggs inseminated in 100 cc sea water + 2 cc 2½ M NaCl, and transferred to

(2) 100 cc sea water + 6 cc 2½ M NaCl. The eggs separated membranes in this solution. Transferred to

(3) 82 cc sea water + 18 cc 2½ M NaCl. This solution produced a strong contraction of all eggs which had formed membranes. Transferred to

(4) Sea water. 90 per cent. of these eggs underwent regular cleavage.

Step (2) was necessary for the removal of internal block to the fusion of the germ nuclei.

HELIOCIDARIS ♀ × ASTRICLYPEUS ♂

For this activation the eggs were washed in sea water and placed in

(1) ⅝ M $CaCl_2$ for 3 minutes; then transferred to

(2) 800 cc sea water + 5 cc n/10 NaOH + *Astriclypeus* sperms; after 3 minutes transferred to

(3) Sea water.

All the eggs formed perfect membranes and segmented regularly. ⅝ M $BaCl_2$ and ⅝ M $SrCl_2$ were used in place of $CaCl_2$ and gave the same results. Segmentation did not take place unless the eggs were transferred to a considerable volume of sea water, as indicated, following the treatment with $CaCl_2$, $BaCl_2$ or $SrCl_2$.

The control in both cases consisted of eggs receiving the respective treatments described above, but with insemination omitted. Without insemination, no membranes were separated and cleavage did not take place. The methods were not interchangeable. *Heliocidaris* eggs were not activable by *Temnopleurus* sperms following the treatment with $CaCl_2$, nor were they activable by *Astriclypeus* sperms following any treatment with NaOH or NaCl, or any combination of these that was tried. On the other hand, *Heliocidaris* eggs which have simply stood in sea water for four hours will, when inseminated with *Astriclypeus* sperms, give as high as 95 per cent. regular segmentation.

These two examples represent the two types of treatment which were found to be necessary in order to obtain cross-activation of the eggs of *Heliocidaris* by the various sperms used. In five of the seven cross-activations of this egg which were made, a preliminary treatment of the egg with NaOH or NaCl or a combination of NaOH and NaCl, a treatment which may be looked upon as increasing the permeability of the egg, was necessary. In the two remaining cross-activations it was necessary to give the egg treatment with solutions of the divalent salts of the alkaline earths, which are regarded as decreasing the permeability of the egg.

Having determined that the sperms used in these activations may be divided into two groups on the egg, it is of interest to find whether this grouping on a physico-chemical basis can be related to any other determinable differences. The only other evident difference is the difference in size of eggs of the different species used. *Astriclypeus* and *Peronella* sperms, the two which form the smaller group, are from species having large eggs. *Peronella* eggs are from .3–.4 mm in diameter. The other group contains sperms from species having eggs that are comparable in size to those of *Arbacia, Strongylocentrotus purpuratus, Lytechinus variegatus,* etc. The idea of natural potency and the relative mass, or the relative surface of the egg to be activated therefore suggests itself. Any discussion of this idea, at this time, would be little more than speculation. There is simply the evidence that *Astriclypeus* and *Peronella* sperms produce too great an increase of permeability when used with small eggs, for activation to be successful.

Six cross-activations of eggs were made with the sperms of *Heliocidaris.* In every instance the only treatment found to be necessary was insemination in sea water to which NaOH or NaOH and NaCl had been added. If this treatment increased the perme-